PROCEEDINGS

OF THE

40th ANNUAL CONVENTION

Of The

WESTERN CANADA WATER

And

WASTEWATER ASSOCIATION

WINNIPEG, MANITOBA

October 19, 20, 21, 1988

WESTERN CANADA WATER AND WASTEWATER ASSOCIATION

WESTERN CANADA SECTION A.W.W.A.

WESTERN CANADA POLLUTION CONTROL ASSOC. W.P.C.F.

PROCEEDINGS

of the

40TH ANNUAL CONVENTION
WESTERN CANADA WATER AND WASTEWATER ASSOCIATION

including the

18TH ANNUAL CONVENTION

of the

WESTERN CANADA SECTION
AMERICAN WATER WORKS ASSOCIATION

and the

16th ANNUAL CONVENTION

of the

WESTERN CANADA POLLUTION CONTROL ASSOCIATION
WATER POLLUTION CONTROL FEDERATION

89-06107/

Proceedings of the

40th Annual Convention
Western Canada Water and Wastewater Association

18th Annual Convention
Western Canada Section
American Water Works Association

16th Annual Convention
Western Canada Pollution Control Association
Water Pollution Control Federation

Published by

Western Canada Water and Wastewater Association
Box 6168, Station A
Calgary Alberta
T2H 2L4

Doreen Munsie
Manager

Library of Congress Catalogue No. TD 201 W42 1988

ISBN 0-921618-00-X

Winnipeg
October 1988

ACKNOWLEDGEMENTS

The Western Canada Water and Wastewater Association would like to express its appreciation and thanks to the individual authors who submitted their papers for inclusion in the proceedings.

Our thanks also to Theodore Snure and Brent Amy, Chairmen of the 1988 Operations Program; to Alf Poetker and Bob Gladding, Chairmen of the Technical Program; and to Dr. Jan Oleszkiewicz and Dan Hooper, Chairmen of the Research Program; for their help in the collection and coordination of the papers.

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CORPORATE OWNERSHIP OF WATER SYSTEMS

Archie R. Pick
Director, Special Projects
Interprovincial Pipe Line Company

INTRODUCTION

In Canada, provincial and municipal governments have been responsible for development and operation of public water systems. As a result of aging infrastructure, population growth and industrial development, there is a growing need for water system renewal and expansion. Under current arrangements these facilities are provided at significant cost to the taxpayer, increasing the financial burden which many governments already carry.

Solutions to this problem vary. In various parts of the world governments are examining privatization programs as an appropriate policy alternative. Water system privatization would divest governments' construction, operation and ownership responsibilities to investor owned, publicly-traded, companies.

This paper examines the background, policy concerns, potential benefits and precedents of investor owned water utilities.

CONCEPTUAL FRAMEWORK

In this paper privatization is defined as the transfer of enterprises from governments to the business sector. Privatization arrangements are intended to compliment fiscal and economic development policy goals of government while providing long-term investment opportunities for business. They are also a means of focussing capital, business and technological skills in new areas.

In practice, privatization can take a variety of forms, including:

- divestiture — the transfer of ownership, control and operating responsibility of a legal entity;
- devolution — the transfer of services or activities previously delivered by government;
- contract management — the transfer of operating responsibilities of a legal entity without relinquishing ownership and control; or
- contracting out — the purchase of goods or services formerly supplied by government (Konrad, 1986:82).

Privatizing through divestiture would be applicable in the transfer of fiscal and operating responsibility for existing municipal or provincial water systems to business interests. Privatizing by either contract management or contracting out does not reduce the financial commitment government must make to fund large capital investment projects.

In the case of corporate ownership of new water systems, government could grant a franchise to an investor owned corporation to provide the service, with the corporation having title to the real property. The franchise agreement would embody the guarantees necessary to protect the

public interest. Kay and Thompson (1986:25), believe that in the case of natural monopolies, such as gas or water supply, franchising may also provide the opportunity to introduce the element of competition into the privatization process.

EMERGING FINANCIAL CHALLENGES

The report of the Inquiry on Federal Water Policy (1985:102), puts the emerging problem of Canadian financing for water services in perspective.

> "Water supply and wastewater systems represent tremendous investment. Total replacement cost of Canadian waterworks and wastewater systems are estimated at $62 billion and $47.5 billion, respectively. This amounts to $3 thousand per capita served.
>
> In 1984, an estimated $2.4 billion in capital cost alone, was spent on providing new or upgraded service, but this is clearly insufficient to provide and maintain the facilities needed."

In Alberta, the task of providing for infrastructure development falls largely to municipalities, assisted by provincial grants. In the coming years the provincial government will face increased pressure to shoulder more of the financial burden from communities and municipalities.

Clearly, the ability of government to respond to these infrastructure requirements will be limited by the timely availability of necessary funds. The infusion of private capital could play a significant role in ensuring the systematic development of future water system needs.

BENEFITS OF CORPORATE OWNERSHIP

Many jurisdictions have discovered that corporate ownership offers a broad range of benefits to the economy, the public and government.

Corporate ownership of water services would allow government to concentrate on other priorities. It reduces demands on government time and resources currently involved in the development and management of water facilities. In the case of the provision of utility services, government would better serve the public interest in regulatory roles when it is not concurrently the financier or operator of that service.

Corporate ownership of water supply systems can provide additional benefits:

- introduces the criteria of economic performance to the water service industry;
- development of technically innovative solutions to water supply, treatment and handling problems;
- ease the shift to a full user pay, or revenue dependency, status for water supply systems;
- create additional sources of revenue with new businesses contributing corporate and property taxes to municipal, provincial and federal governments; and
- establish new areas of investment opportunity for individual Canadians.

THE PUBLIC INTEREST

When significant change is suggested, there is a tendency to adhere to the status quo in terms of how things are done and who does them. Apartment from this natural tendency, two key issues seem to particularly effecting thinking about corporate ownership of water supply systems: the seeming complexities of regulation or other mechanisms to protect the public interest and the concept of profit.

In Canada, many provinces have opted for government ownership and operation of utilities, while others have favoured regulated corporate ownership. In tracing the development of utilities in Canada, Gordon (1981:43) concludes that:

> "The degree of government ownership of natural monopolies in Canada is clearly the result, to a considerable extent, of emotionally held political philosophies, fear of big interests, and — perhaps in early days — the absence of a regulatory authority in which the public could have confidence."

In the case of investor owned and operated utilities and services, the regulatory framework and procedures are becoming more standardized. The public interest can be protected by ensuring that corporations:

- adhere to requirements represented to them under a structured regulatory regime or through the terms of a contractual agreement;
- have substantial financial resources;
- exhibit sound management practices; and
- demonstrate corporate longevity and success in other regulated environments.

Corporate ownership of public services in Alberta is not a new phenomenon. Examination of the regulation and control of gas distribution and electrical utilities, inter-city bus and truck transport services, cable television and telephone services, and solid waste management provide examples of how the public interest can be served within the framework of corporate ownership.

The concept of corporate ownership also requires consideration of the profit component of the venture. A corporation that does not operate at a profit is destined to failure. A successful corporation will generate a profit which in turn is reinvested or paid out as taxable dividends. The return which would be earned on the equity investment comprises only a small portion of the total cost.

The spread between return on equity and the debt interest rate will reflect relative risks, alternative investment opportunities and financial market conditions at the time of financing. Assuming debt is on the actual cost basis, only the difference between the equity return level and the debt interest rate can be called the "profit element". If that spread is 4 per cent and the equity component is 40 per cent of the total capital cost, the effect is to add 1.6 per cent of the capital cost of the project to the cost of service.

CORPORATE OWNERSHIP OF WATER SERVICES IN CANADA

In Canada, corporate ownership of water supply systems is not presently extensive, but there are

indications of future growth potential. As of mid-1986 more than 40 privately owned water supply utilities were operating in the country, serving about 75,000 people. Quebec is currently the Canadian leader in privately-owned water systems with 20 facilities in operation.

Interest in the concept of water supply privatization has been growing in some areas of the country. In Alberta the examination of corporate ownership of provincial water service systems is ongoing. Several Alberta municipalities are considering the sale to, and operation of their water systems, by investor owned companies.

CORPORATE OWNERSHIP OF WATER SERVICES IN OTHER COUNTRIES

There have been several notable experiences with corporate ownership of water service systems in other countries such as the United States, Great Britain and France. A review of these experiences, based on an article by MacLaren (1986), follows.

United States

In the United States about 20 percent of the population is served by 200 private or investor owned water utilities. Water companies in the U.S. are regulated by state public utilities commissions. A typical capital structure for U.S. water utilities is 35 per cent common equity, 5 per cent preferred equity and 60 per cent debt.

The American Water Works Company is the largest water supply company in the United States, owning and operating a number of local systems in 19 states. American Water Works operates it business under state regulatory authorities which define its service areas and control the rate of return on the Company's investment.

France

In France, five investor owned utilities provide municipal water supply or wastewater disposal services. The three largest companies meet the water requirement of about 60 per cent of the population. Employing more than 40,000 people, the companies retain qualified personnel in all professional skill areas which enables them to design, construct and operate complex utility systems.

Great Britain

In England and Wales, water supply, wastewater and storm drainage services are the responsibility of 10 regional water authorities. The authorities operate relatively autonomously under central government legislation and regulation. As a result of recent government initiatives, private companies are now supplying water to 20 per cent of the population as agents of the regional water authorities.

The water authorities are self-supporting and must raise all needed revenues from their customers, with rates established on a full-cost pricing basis to permit full revenue dependency. Owning to the strong performance of the water authorities, government is rapidly advancing plans for the sale of the water supply and sewage functions to the corporate sector. One of the authorities which is actively seeking to be privatized is the large Thames Water Authority (Kay and Thompson, 1986:31).

INTERPROVINCIAL PIPE LINE LIMITED

Interprovincial Pipe Line Limited has entered the water services industry. Projects undertaken by Interprovincial will be financed, owned and operated by the Company. This approach will provide a new standard of reliable and economic service.

Interprovincial is an Alberta-based company owning and operating the largest liquid pipeline system in the western hemisphere. The Company is publicly traded on the Toronto Stock Exchange.

Interprovincial Pipe Line is prepared to build, own and operate water supply systems. The Company has a proven track record of planning, building and operating liquid pipeline systems in a fully regulated environment with over 11,000 kilometers of pipeline and 1,000,000 horsepower of installed pumping capacity.

Company personnel have extensive experience in financing, planning, construction and supervision of major projects, dealing with broad public and regulatory issues, and proving on-going operations and system maintenance services in a safe, cost-effective, social and environmentally responsible manner.

CONCLUSION

The ownership of water services by investor owned companies is an appropriate policy vehicle to promote both systematic and timely development. The privatization of water services offers an attractive opportunity for government to re-direct the future use of capital and public debt at both provincial and municipal levels.

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THE DEVELOPMENT OF A HAZARDOUS WASTE MANAGEMENT SYSTEM IN MANITOBA

R.J. Cooke and E. Yee
Manitoba Hazardous Waste Management Corporation

INTRODUCTION

Modern societies with industrial and resource based economies generate a significant quantity of waste material. A portion of this material is harmful to the biophysical environment and, in some cases, to human health, when disposed of in a random or uncontrolled manner. In addition, it is a cumulative problem with the impacts building up over time and finally being manifest as major or even catastrophic events having significant environmental, social and/or economic implications.

In recent years, the management of these materials have become a major social and economic priority. In this paper, a general overview of the hazardous waste issue is provided, the experience of others is outlined and the plans for the development of a management system in Manitoba are described.

THE HAZARDOUS WASTE ISSUE

Materials considered to be "hazardous" or "special" wastes include a wide range of substances extending from well publicized chemicals and contaminants such as dioxins or PCB's to relatively common materials such as solvents, cleaners, petroleum products and paint residues. In Canada, they are defined under provincial regulation with the federal government providing uniformity through the Transportation of Dangerous Goods Act [1] and the new Canadian Environmental Protection Act [2]. Specifically excluded in the context of this paper are explosive and radioactive wastes which are separately managed under federal jurisdiction.

Current national regulations [1] define 3126 different hazardous materials in general use under the international classes listed with typical examples in Table 1. The number of such materials can be expected to grow as a result of both technological advancement and economic growth. As evidence of this, it is estimated that over 50,000 commercial chemicals are currently produced by North American industry, with this increasing by about 2,000 each year [3]. In the future, this number is expected to grow even more dramatically with the addition of products from the emerging technologies. Only a small proportion of either new or existing materials have been fully assessed as to their impact on environmental quality and human health. However, the capacity and the legislative requirement to do so is increasing [2]. This will inevitably lead to more materials being classified as hazardous and the resultant wastes requiring competent treatment and disposal.

TABLE 1

CLASSES AND EXAMPLES OF COMMON HAZARDOUS MATERIALS

Class	Name	Example
2	Gases	Aerosols, Ammonia solutions, Carbon dioxide, Coal gas, Compressed gases, Methane, Oil gas, Propane, Vinyl chloride
3	Flammable Liquids	Acetone, Adhesives, Alcohols, Brake Fluid, Gasoline, Kerosene, Printers ink, Paints, enamels, lacquers, stains, varnish & polishes, Liquid tars, Liquid wood preservatives, Turpentine
4	Flammable Solids	Alkali metal alloys, Metal alkyds, Aluminum powder, Barium alloys, Calcium hydride, Camphor, Celluloid, Charcoal (activated), Fertilizer ammoniating solution, Iron oxide, Lithium batteries, Matches, Nickel catalyst, Rubber scrap, Textile waste, Zinc powder
5	Oxidizing Substances & Organic Peroxides	Aluminum nitrate, Ammonium nitrate fertilizers, Calcium chlorite, Calcium nitrate, Benzoyl peroxide, Hydrogen peroxide, Lead dioxide, Medicines, Potassium nitrate, Sodium nitrate
6	Poisonous & Infectious	Aerosols, Arsenic compounds, Cresols, Cyanides, Disinfectants, Dyes, Infectious substances (human & non-human), Medicines, Mercury compounds, Motor fuel anti-knock mixtures, Organic phosphate compounds, Phenols Pentachlorophenol, Pesticides
8	Corrosives	Acrylic acid, Aerosols, Ammonia solutions, Batteries (with acid), Battery fluid, Caustic potash, Caustic soda ash, Corrosive liquids, Sodium chlorite solution
9	Miscellaneous Substances	Aerosols, Aluminum sulphate, Ammonia solutions, Ammonium nitrate fertilizers, Asbestos, Chlordane mixtures, Dichlorobenzene Dieldrin, Heptachlor, Methoxychlor, Polychlorinated biphenyls, Strychnine mixtures, trichlorethylene, 2,4,5-T

NOTE: Products and substances, including waste materials in Class 1, Explosives and Class 7 Radioactives, are classified and controlled by the Explosives Act (Canada) and the Atomic Energy Control Act (Canada) respectively.

In terms of quantity, it is estimated that 2,783,000 tonnes of provincially regulated hazardous waste are generated in Canada on an annual basis (4). The estimated regional distribution of this waste is illustrated in Table 2. While the largest proportion is generated in Central Canada, particularly Ontario, all regions contribute significant amounts. Estimates for Manitoba, based on the province's economic characteristics and population, would suggest that 33,300 tonnes/year are generated (4). It should be noted that these estimates are dated and do not reflect current regulation or awareness. The extrapolation on the basis of population of

more recent data from Ontario (5), where the most detailed survey work has been done, suggests that actual quantities may be twice those stated below. The most current direct survey data for Manitoba indicates that approximately 20,000 tonnes/year is available for treatment and disposal (6). This number differs from that quoted below as it is based on data collected from specific waste generators who would be expected to present their wastes for treatment (i.e. capturable waste). However, like the 33,300 tonne estimate based on demographic and economic characteristics, it does not reflect current regulatory and social attitudes.

TABLE 2

HAZARDOUS WASTE GENERATION BY PROVINCE IN 1982
(Tonnes)

Province	1982 Population	Total Hazardous Waste Generated (Tonnes)
Alberta	2,345,500	67,500
British Columbia*	2,837,700	66,300
Manitoba	1,049,600	33,300
New Brunswick	709,200	48,900
Newfoundland	580,800	20,700
Nova Scotia	863,000	106,800
Ontario	8,854,700	1,407,800
Prince Edward Island	124,505	400
Quebec	6,530,000	951,900
Saskatchewan	997,400	42,200
TOTAL	24,892,400	2,763,800

* Includes the Territories (Source Proctor & Redfern et al, 1984)

It should be noted that all of the above quantities relate to societies current hazardous waste generation rates. It does not include the large quantity of material identified as hazardous due to contamination from past practices and which requires management in the course of environmental remediation. Some measure of this can be obtained from estimates in the United States where the overall waste market including volumes from remediation are approximately five times the generation rate (7,8).

In the past, we have not been particularly discriminating in the manner in which wastes have been managed. The result has been that the vast majority of hazardous wastes have been disposed of in municipal landfills and sewer systems or by direct release to the land or surface water (6). It is only recently that waste management at source through reduction, reuse, recycling and recovery, or using off site treatment and disposal facilities specifically designed for this purpose.

Historically, a number of barriers to the adequate handling of these wastes have existed, including:

a) **Poor awareness** of the hazardous waste issue was the major reason for the relatively recent realization that a problem exists. This has largely been overcome in the last decade with the growth in society's sensitivity to health, safety and environmental values. Also contributing to public awareness is the occurrence of widely publicized events related to such things as the discovery of toxic waste dumps, mercury poisoning and accidental chemical spills. However, there still remains a tendency toward minimizing the urgency of taking action unless there are highly visible impacts. In effect, a societal choice exists between a preventive approach through anticipatory action (i.e. education, regulation, provision of facilities) or waiting until the problems become visible prior to taking remedial action.

b) **Absence of regulation** covering hazardous wastes has been a traditional barrier. It is an unfortunate fact that sanction and control are required to stimulate action by waste generators as well as to ensure that the responsible generator is not placed at an economic disadvantage. The basic regulatory framework is now being established in most jurisdiction in Canada, albeit with variations in comprehensiveness and consistency (9). In this context it is important to recognize that the existence of regulations must also be supported by the capability to enforce them. Unfortunately, effective enforcement is often limited by the resources available to do so and by the availability of adequate treatment and disposal alternatives.

c) **Lack of appropriate treatment and disposal alternatives** restricts effective waste management. Although regulations requiring the proper treatment and disposal of hazardous materials have been coming into effect, few facilities providing this service are available, and access to them has been limited by jurisdictional and economic barriers. These include the high initial capital cost and business risk involved, the difficulty in siting and approval facilities at a local level and uncertainties as to long term public policy.

d) **Economic impediments** exist because the cost of proper management are substantially higher than those incurred previously using traditional practices. These costs many significantly alter the basic economic viability of a waste generating enterprise. In turn, this raises questions related to how these costs are distributed equitably so that economic development is not negatively or unfairly impected. Furthermore the costs of providing the proper management capability are significantly affected by economies of scale with the result that such as Western Canada are less able to provide cost effective solutions than more populated regions.

EXPERIENCE ELSEWHERE

General

Once government, industry and the public have developed some degree of recognition that a problem does exist the response has generally been to initiate collective action involving two aspects. Firstly, the mechanisms to control hazardous wastes and their management through regulation have been pursued. Secondly, the development of a dedicated management capability to recycle, recover, reuse, reduce, collect, transport, store, analyze, treat and dispose of these materials has been addressed. The coordinated management capability encompassing both aspects and inclusive of the necessary infrastructure and the facilities to accomplish this, comprise what is referred to as a "Hazardous Waste Management System".

The following provides a summary of facilities and system development in Western Europe, the United States and other Canadian provinces.

Western Europe

The problem has been evident in Western Europe for some time due to the region's high level and long term history of industrialization. Therefore, it is not surprising that this area has been the most advanced, both in terms of control measures and the provision of facilities [10]. This is particularly true in Northern European countries. Operational hazardous waste management systems providing a complete range of services have been in existence for at least 10 years in Denmark and West Germany. More recent capability has been developed in Sweden and Finland. In addition, these countries have specialized capability for specific industries and waste streams. A comprehensive or integrated capability in other European countries is less developed, although commercially operated specialty facilities do exist in France, the United Kingdom and Italy.

Most of the fully integrated facilities are collectively owned with equity participation by municipalities, senior governments and, in some cases, the generating industries. Generally, they are operated as utilities with the user fees being set on a regulated or quasi-regulated basis to ensure social and economic accountability, as well as to recover operating costs.

United States

The management of hazardous waste is currently viewed as a majority priority in the U.S., with substantial levels of federal funding and regulatory resources being directed toward the problem. Likewise, many states are actively pursuing the establishment of facilities and a large commercial waste management industry has developed to supply technology and services.

The problem in the U.S. is viewed as having two dimensions. The first is the control and adequate management of wastes as they are generated. The second relates to the clean up or remediation of the results of past practice.

The annual generation of rate of non-radioactive hazardous wastes in the U.S. is estimated to be approximately 50 million tonnes or approximately one pound per person per day [7]. In recent years, hazardous waste has been subject to increasingly stringent regulation and, associated with it, the assignment of major long term liabilities to the waste generator. However, the capacity to effectively manage this volume of material in off-site facilities remains generally short of the demand due to the difficulty in siting such facilities and the difficulty in obtaining approvals for current technologies. The result is a major move on the part of waste generators toward source based waste management, either through conservation oriented measures [reduction, recycling, reuse, recovery] or on-site treatment and disposal.

The remediation of sites where hazardous wastes have been disposed of in the past is also a major priority in the U.S. As of October 1986, 25,000 sites, potentially requiring remediation, have been reported with 888 of them being proposed or designated as national priorities for action and so called "Superfund" action [11]. This fund was originally set at $1.6 Billion in 1980 with financing through selective taxation of crude oil and certain chemical products. In 1986, the fund was increased to $8.5 Billion for a 5-year period in recognition of the problem's magnitude [12]. It is currently estimated that the eventual remediation costs in the U.S. will be $300 Billion [14].

With respect to facilities offering hazardous waste management capability, a wide range are available on a commercial basis including incinerators, physical/chemical treatment plants, stabilization facilities and landfills [8, 14]. However, few of these facilities can provide a fully integrated service. Moreover, the use of hazardous waste landfills, which has been the most common method of management, is being discouraged where pretreatment and stabilization are not provided for. Complicating the reduced availability of landfills is the difficulty in developing more modern facilities due to siting opposition and to the complicated regulatory approval process required. The combination of an increasing need for facilities and the hesitancy of private operators to pursue new facilities has resulted in state governments stepping in to develop publicly sponsored facilities, often on a joint venture basis with competitively selected commercial operators.

Canada

In Canada, the response to the issue has been relatively recent, with serious regulatory initiatives starting in the late 1970's and still remaining under development in many jurisdictions [9]. Similarly, the development of treatment and disposal facilities is relatively new and is described in the following.

A major distinction of the Canadian process of facility development, in comparison with that of the U.S., has been the role of public enterprise as the initiator and proponent. Provincial governments through their own commercial or quasi-commercial agencies rather than the private sector, have taken the lead in acting as the proponents of such facilities. In part, this reflects the Canadian tradition of using public enterprise as a vehicle for providing collective services for the public good. It also reflects the reluctance of the private sector to take risks in this area, particularly when the size of the waste market and the potential for economic returns are relatively small. In addition, it is generally recognized that such facilities will be controversial and require a high level of public support to succeed. Government agencies have been perceived to offer a greater measure of public accountability and therefore a greater chance of success.

a) **Ontario** - Due to its proximity to the U.S. industrial heartland and its own heavy industrialization, Ontario began addressing the hazardous waste issue relatively early. Initially the process paralleled U.S. experience with the establishment of a number of privately operated commercial facilities. Currently, these include a large scale liquid incineration plant, physical/ chemical treatment and secure landfill in Sarnia, and several smaller specialized physical/ chemical treatment facilities in the Toronto/Niagara area. These facilities constitute a major portion of the capability in Canada at this time. However, their current capacity is substantially less than the volumes generated and many wastes, particularly contaminated solids and chlorinated solvents, cannot be handled.

   The need for greater and universal capability lead the provincial government to form a Crown Corporation in 1982 to develop a large scale, fully integrated facility for the province. The Ontario Waste Management Corporation (OWMC) has undertaken an extensive technical and environmental assessment program toward this end. The Corporation has completed the preliminary design of a 150,000 tonnes/year facility, selected a proposed site in the Niagara area and has submitted an Environmental Impact Assessment to the Ministry of the Environment for approval to proceed with construction. The approval process for this development will take several years and it is scheduled for completion in 1992 [5] at an overall cost of $250 Million [19].

b) **Quebec** - In Quebec, one major private commercial facility, providing physical/chemical treatment, waste stabilization and landfill services, has been operating since 1983. While initially uneconomic due, at least in part, to the absence of regulations in the province, it is currently being sustained by the importation of material from the U.S. and other provinces (70% of their market). A privately operated rotary kiln incinerator is also under consideration but the date that it will be available is uncertain at this time.

c) **Alberta** - Based on public hearings and Alberta Environment studies (15,16), the Alberta Government initiated the siting of a fully integrated facility in 1982, under the auspices of a Crown Corporation, the Alberta Special Waste Management Corporation (ASWMC)(17). The actual facility development was undertaken as a joint venture between ASWMC and a private company who acts as the operator. The 20,000 tonnes/year facility is located in North Central Alberta near Swan Hills and consists of an incineration plant, physical/chemical treatment plant, stabilization capability and landfill plus the necessary administrative, technical and environmental monitoring infrastructure (18). Facility costs were $50 Million.

Commercial operations began in late 1987 with full operational status being reached in the summer of this year. However, while this facility is the first fully integrated plant in Canada, it is not currently available on a commercial basis to any wastes generated outside of Alberta due to the policies of the provincial government.

d) **British Columbia** - In early 1988, a provincially appointed commission selected a private consortium to develop a fully integrated commercial facility in the province. Currently this group is looking for a site and expects to have a facility in operation in late 1989. The estimated cost of the 20,000 tonnes/year facility itself is $15 Million excluding the collection system, site costs, support services and closure costs. The latter costs are estimated to be $5 Million (20).

e) **Other Provinces** - Most other provinces in Canada have initiated preliminary studies related to facilities but none (except Manitoba) have pursued facility development. Most have concluded that the market is too small to sustain a facility and are hoping to obtain access to facilities elsewhere (21).

MANITOBA HAZARDOUS WASTE MANAGEMENT PROGRAM

Background

Interest in the issue in Manitoba dates from the early 1970's when the Department of Environment and Workplace Safety and Health (EWS&H) and its predecessors initiated several programs in this area related to such things as pesticides and chemicals in institutions. This work involved the establishment of a temporary hazardous waste storage facility at Gimli which has been available for pesticide residues and various chemical wastes collected through public programs operated by the regulatory authorities.

Also of note was the action taken by Manitoba Hydro in the early 1980's respecting the treatment and storage of PCB's. Hydro installed a chemical treatment facility to process contaminated oils, and have a long term program to remove such contaminants from their system as well as provide limited services to others (22). Manitoba leads the country in the volume of low level PCB contaminated material treated (23). Hydro also operates a PCB storage facility for material that they cannot treat. Limited access to these facilities is available to private and institutional generators of this material on a cost recoverable basis.

Examination of the hazardous waste issue began in a systematic way in 1982 with the initiation, by the provincial government, of a long term multi-phase hazardous waste management program [6]. The program was designed to occur in three distinct phases:

a) Phase I - Develop an Information Base
b) Phase II - Design and Propose a System
c) Phase III - Implement and Operate the System

The first phase of the program was pursued from 1982 to 1987. It focused on the development of public awareness through a series of public hearings [24,25] and a public symposium involving a wide range of interested parties [26]. In addition, EWS&H conducted a number of preliminary technical studies on the nature of the wastes generated in the province, the types of facilities that might be developed and a preliminary economic analysis of various generic facility options [6,27]. At the same time, the basic regulatory framework for the control of hazardous waste was established [28]. A listing of the relevant legislation and regulations is provided in Table 3.

The general results of Phase I may be summarized as follows:

a) A preliminary estimate indicates that 20,000 tonnes/year of hazardous wastes will be available to the provincial management system.

b) The estimated distribution of waste indicated a concentration in Winnipeg (40%) and in the neighboring eastern (23%) and western (25%) regions of the province.

c) 75% of the waste was estimated to consist of inorganic materials. Organic waste accounted for the remaining 25%.

d) It was recognized that the estimated quantity, distribution and waste type requires verification, particularly with respect to the actual amounts and types of waste that a system will ultimately see when the impact of both regulatory enforcement and source based waste management are better known.

e) The present disposition of these wastes is primarily to municipal sewer and landfill facilities. Direct treatment, storage or recycling account for a small proportion of wastes generated.

f) A public consensus exists that a management system for hazardous waste is required in the province.

g) The proponent of the overall hazardous waste management system should be a commercial public corporation operating independently from the regulatory authorities.

h) The specific form that the system should take requires further study, particularly with respect to its sizing, the technologies required, the economic basis under which it will operate and the location of its facilities.

Manitoba Hazardous Waste Management Corporation

It was recognized during Phase I of the program that a proponent, independent of the regulatory authorities, would have to exist for the development of the system to proceed into Phase II. During Phase I, EWS&H acted in both capacities. However, once a system was to be pursued in detail, the two roles would have to be split to avoid an inherent conflict of interest.

The choice of a public corporation as this development vehicle was made in part by the absence of any private sector alternatives. The choice was consistent with the preference of virtually all interested parties who expressed their views during the Phase I Clean Environment Commission hearings [24,25]. Other supporting rationale included a need to coordinate various system components, the coverage of liabilities inherent in the undertaking, assurance of equitable and universal access, provision of system security and continuity, public accountability and the need for public funding.

The Corporation was created with the passing and proclamation of the Manitoba Hazardous Waste Management Corporation Act in November 1988 [29]. It was established as a commercial Crown Corporation, reporting through its Board of Directors to a responsible Minister with its equity held by the Minister of Finance. Initial financing is provided through the provincial Loan Act with a maximum contemplated capital borrowing authority of $35 Million.

Its mandate is to plan and operate a hazardous waste management system which will safely dispose of hazardous waste in accordance with regulations and standards prescribed by the Minister of Environment and Workplace Safety and Health. This is to be done through the coordination of the various elements of the system, which may include collection, transfer, storage, treatment and disposal of waste as well as the promotion and facilitation of waste management at source. It is to be accomplished in an efficient, dependable fashion, impacting positively upon the provincial economy and giving priority to hazardous wastes generated in Manitoba.

In August 1987, the Corporation became operational with the hiring of its first staff. Since that time it has established itself as an independent organization having a professional staff of eleven recruited from both the private and public sector. As is described in the following section, the first task undertaken by the Corporation has been the development of an overall strategic plan for the system and the initial implementation of this plan. This work is targeted toward the submission of a detailed facility and business plan in late 1989 for regulatory and capital funding approval.

System Development Strategy

The first task undertaken by the Corporation was the formulation of a long term strategic plan for the development of a provincial hazardous waste management system. Using the results of the overall program's first phase and a careful review of experience elsewhere, a basic approach has been established and its being pursued.

This strategy defines the basic requirements of the system as being:

a) provision for the management of these wastes in a manner that protects human health and safety and environmental quality.

b) universally accessibility in that it will handle all provincially generated and regulated hazardous wastes presented to it.

c) provision of services as soon as possible, since regulations are now in place, and the principle environmentally sound alternatives to generators are high cost out of province commercial operators.

d) encompassing the complete spectrum of waste management options with the 1st priority attached to the management of waste at source through reuse, recycling, recovery and reduction.

e) affordable to its users in that its costs do not unduly penalize compliance with regulation, discourage use and/or impose economic disadvantage.

f) accessibility on a equitable basis within the province such that service is provided on the same basis regardless of waste generation location or amount of waste produced.

g) affordable to taxpayer in recognition that the public financial resources available for it are limited and therefore, it must be developed and operated with the optimum level of public expense, financial risk and control.

h) pursuit with a high degree of public involvement, input and acceptance.

In attempting to satisfy these requirements, examination of the experience elsewhere shows that a number of constraints or risks exist that need to be addressed in implementing the strategy. More specifically, the lessons learned from this experience include:

1) It is difficult to predict the actual size of the waste market prior to developing facilities, leading to the risk of incorrect sizing and facility duplication.

2) A significant portion of the potential market is most economically serviced by source based waste management strategies.

3) The economic visibility of the system is enhanced by maximizing the size of the market accessed and is limited by restrictions on movement of waste between jurisdictions.

4) To be economically viable, a system accepting all waste presented to it (i.e. a universal system) must have access to more profitable waste streams and the revenues that may be generated through source based waste management in order to offset the cost of servicing small and remote generators.

5) A degree of public financial support will likely be required for any universally and equitably accessible system in the form of initial capitalization, provision of infrastructure, liability coverage and subsidy of some waste streams.

6) System viability requires the existence of a comprehensive regulatory infrastructure, including enforcement capability.

7) The ability to successfully locate and operate facilities requires the development of public acceptance and understanding at a local level as well as the sustained public policy commitment of governments.

8) The time to put a system in place will range from a minimum of 5 years to in excess of 10 years, depending on the level of public acceptance and the sustainability of public support.

In summary it was concluded that for the Corporation to satisfy the above system requirements and at the same time provide a cost effective system within a reasonable time frame, a different approach than that adopted by others was warranted. A characteristic of virtually all other

similar undertakings has been to focus from the outset on the development of a dedicated facility providing a complete range of treatment and disposal capability. This has required commitment to a significant capital outlay and specific technologies early in the development process, usually prior to an accurate estimate of the market or the potential returns being available.

As an alternative, the Corporation has opted to pursue the development of the system incrementally on a component by component basis, from the waste source forward. This involves placing a high priority on waste reduction at source in order to identify waste streams that can be most economically dealt with by the generators as well as those that are best dealt with in collective treatment and disposal facilities. This approach serves to enhance the conservation ethic, provides the most economic solutions to many waste streams, places reasonable costs with the generator and perhaps most importantly identifies those wastes that need not be accommodated in the new facilities to be developed for collective waste management.

To respond to the near term need for a collective waste management capability, the Corporation is focusing its initial facility development work on investigation of collection, storage and volume reduction capability rather than on full scale treatment and disposal facilities. This can be provided relatively quickly and at a lower initial capital cost.

However, in contrast to the more traditional approach of committing to a fully integrated treatment and disposal capability from the outset, the Corporation will defer this step until a more accurate characterization of the market is available, out of province disposal options are tested and a full assessment of appropriately scaled technologies has been done. In this way options that may allow for the optimization of the system will not be precluded.

With respect to the selection of technologies, the Corporation's approach gives recognition to the fact that those available and their economic scale and flexibility are changing rapidly. Until recently the options available where largely limited to large scale fixed base processes for thermal and physical treatment of waste, supported by modifications of conventional landfill technologies for residue disposal. However, the potential exists within the development time frames envisioned for the system to explore and utilize a number of smaller scale and/or transportable treatment technologies that area gaining acceptance in source based waste management and site remediation applications. Such technologies, coupled with appropriate site infrastructure planning may offer the flexibility necessary for cost effective incremental development as well as the ability to utilize the most current proven technology as the need is identified.

The physical development of the system is planned to occur in three stages. Stage 1 involves undertaking the necessary study, design, assessment and market development work such that a concrete proposal for the first increment in the system's facilities can be put forward for the appropriate regulatory and financial review. In this stage, study work will also be undertaken related to market and business options, the provision of services to waste generators where not currently available, facilitation of source based waste management initiatives and conceptual level work on the configuration of the overall system.

Stage 2 will involve the building and start up of the "basic system facilities" planned and approved in Stage 1. In addition, the more detailed study, design, and assessment work necessary for the "full system facilities" will be undertaken such that a formal proposal for their implementation can be made. Stage 3 will involve building the full system.

With respect to overall timing, Stage 1 will be completed and Stage 2 will being in early 1990 with the receipt of the necessary regulatory and funding approvals for the basic system development. Stage II will be completed in 1991. Assuming that dedicated treatment and disposal facilities are justified, these will be constructed in Stage 3 with completion as early as 1993. It should be noted that this schedule is optimistic, given the experience of others. It depends on the timely receipt of both regulatory and financial approvals, as well as the maintenance of a high level of public acceptance particularly at the local level.

State 1 Activities

The Corporation's current activities are directed toward planning the system and establishing it's feasibility in environmental and business terms. This work is divided into five major activity areas.

a) **Established Programs** - The Corporation is undertaking responsibility for a number of programs previously administered by EWS&H. The rationale for this transfer was the incompatibility and potential conflict of interest involved in the delivery of hazardous waste management services by a regulatory authority. These programs provide a useful and necessary public service in the absence of an overall hazardous waste management system, both as vehicles to maintain public awareness of the issue and to provide an outlet for wastes that would not otherwise have competent custody.

   The specific activities involved are the operation of the Gimli storage facility, administration of the provincial household hazardous waste collection initiative and participation with Manitoba Hydro in PCB management.

b) **Waste Identification and Reduction** - This activity involves the overall characterization of the provincial hazardous waste market in quantitative and technical terms, along with the initiatives the Corporation is undertaking to promote source based waste management. Five specific activities are being pursued; waste exchange, industry group studies, the generator support services program, analytical capability development and waste characterization.

   The Corporation currently funds an independent organization to administer the Manitoba Waste Exchange which provides an information service on waste materials that may be of value to others. This service is being integrated with the Corporation's generator service and waste characterization work to provide a more proactive vehicle for waste reduction.

   Several industrial and institutional groups producing specialized waste streams have been identified as candidates for some form of collective volume reduction, treatment and disposal capability. The Corporation has undertaken a facilitation role through provision of technical assistance to these groups, participating in technical feasibility studies and assisting in obtaining regulatory approvals. In addition, the potential to participate in the development of specialized facilities on a joint venture basis is being pursued where an economically viable and potentially profitable opportunity is identified.

   The Corporation has developed a capability to provide technical assistance to waste generators respecting waste management at source. This capability includes the identification of commercially available analytical and disposal capability, advice on available waste reduction and recycling technology and waste audit services. The service is offered at no charge where it serves to assist in longer term market development. However, it is not intended to compete with commercially available consulting services where these are

available. Associated with this activity is the evaluation of the Corporation's own long term analytical requirements. Options being investigated include the utilization of existing government facilities, developing commercial capability on a joint venture basis or contracting work to existing facilities.

A major activity in this area is the characterization of the provincial waste market. With the original data developed during Phase I as a base line [6], the Corporation has initiated a comprehensive study of this market. Using both internally generated data from the above activities and an external study, the quantities, type, distribution and availability of waste are being estimated. This work will provide input into the business planning and facility development activities described below.

c] **Facility Development** - This work is directed toward the definition of the technical scope of the facilities that the Corporation may develop, including the identification of technologies, the conceptual design of the facilities and associated infrastructure and the development of capital and operating cost estimates. In addition, it involves the site selection work and the environmental assessment studies required to support it.

The engineering work required to define the technical scope of the system will be undertaken in four parts. The first part involves the critical review of the Corporation's development approach from a technical perspective, a review of appropriate technologies and production of preliminary facility option descriptions. This will be followed by more detailed technology evaluation and selection studies. The basic design of the initial facility increment will then be undertaken to a level of detail needed to accurately define the Stage 2 capital cost estimates and complete the detailed environmental assessment. In parallel with this work, the conceptual design basis for the full system will be developed sufficiently to complete a preliminary site specific environmental assessment and provide longer term cost planning information.

The facilities siting component of this activity involves the systematic process of establishing siting criteria, applying these to the province on a progressively smaller scale and ultimately identifying several technically acceptable sites. Detailed evaluation of these will then be undertaken in terms of environmental impacts as well as economic and engineering factors. The result will be the selection of one or more technically and environmentally acceptable sites. Currently, the formal process for this work has been documented [30] for consultative discussion with various external groups. The development of site selection criteria is underway along with their application to provincial level constraint mapping studies. Completion of this work will lead to a major public information and consultation initiative specifically directed toward site selection. It should be noted that it is the Corporation's intent to locate a site capable of hosting a fully integrated facility, even though the initial development will not necessarily involve the complete spectrum of treatment and disposal technologies.

d] **Business Plan Development** - This activity is directed toward the assessment of the various business structure options available for developing and operating the system in subsequent stages, defining the financial and market potential of them and doing the detailed economic analysis necessary to select a specific option. All of this information will be brought together into a formal business plan to be presented for review as part of obtaining financial support for continuing the undertakings into subsequent stages.

In association with this work the potential scope of the undertaking is being evaluated

through preliminary investigation of the concept of regionally based system servicing markets in adjacent jurisdictions.

e] **External Affairs Management** - Inherent in an undertaking of this nature is need to gain a high level of understanding and acceptance with a wide range of external stakeholders. This activity is directed toward achieving this through the development of an effective public information and consultation program, providing socio-economic impact assessment data in support of the siting activity and developing a comprehensive cost/benefit analysis of development proposals in social terms.

It should be noted here that the Corporation's approach in this area is directed toward development of a "co-management" model where major stakeholders have an active and meaningful role in the Corporation's decisions. In particular, this is intended to be locally oriented where the costs and risks associated with the development are traditionally perceived to be the greatest.

Current work is focused on implementing an effective public information program covering the Corporation's current activities. A number of information products have been produced, ranging from service and issue oriented brochures to technical reports. In addition, a resource centre is being established to provide various stakeholders and the public with access to current technical information on the subject. Presentations to a wide range of stakeholder groups such as industrial associations, technical societies, public interest groups, and municipalities are being given on a regular basis. Work has also begun on the social considerations related to facility siting including studies on compensation policies and cost/benefit analysis.

SUMMARY AND CONCLUSIONS

The development of a comprehensive capability to manage hazardous wastes in an environmentally sound manner is a complex undertaking. A good start on it has been made in Manitoba, particularly due to the efforts of the Department of Environment and Workplace Safety and Health, and the Clean Environment Commission. These organizations, through the development of a sound information base and, perhaps most importantly, the creation of a high level of public awareness in the issue, have given the Manitoba Waste Management Corporation a solid base to work from.

The adoption of an incremental approach to the development of the system offers significant advantages. It's emphasis on source based waste management should lead to the most economic solutions for many waste streams and minimize the investment in downstream facilities. Perhaps as importantly it will assist in answering the common criticism that the development of waste management facilities promote waste generation [31]. The component by component development of new facilities should also allow for lower near term capital outlays and offers the flexibility to access the most appropriate technologies and facilities in other areas.

In undertaking this task the Corporation recognizes that it will have to deal with a wide range of concerns, issues and interests. This requirement is manifest in the variety of public policy issues that will have to be addressed as the system is developed. These include:

a] The need to maintain a high level of public acceptance of the undertaking, a factor that historically has most often dictated the success or failure of such undertakings [32].

b] The demonstration on an ongoing basis of the need for the undertakings as it competes with other social and economic priorities.

c] Its development as an economically justifiable undertaking, recognizing that public and private resources available to it are finite.

d] The establishment of a business structure that allows it to meet its economic and social objectives.

e] The resolution of policy issues related to the optimum utilization of capability elsewhere and the access of others to capability in Manitoba.

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RESEARCH PROGRAM OF THE AWWA RESEARCH FOUNDATION

James F. Manwaring, P.E.
Executive Director
AWWA Research Foundation

The American Water Works Association Research Foundation (AWWARF) is the centralized research organization of the North American water supply industry. More than 3000 water utilities, thousands of individuals, and hundred of other organizations in the United States and Canada support the research efforts of AWWARF through payment of subscriptions, contributions, and dues.

AWWARF is a non-profit corporation governed by a Board of Trustees that consists predominantly of utility representatives. The Trustees set the organization's policies and oversee its management. The Board selects the research projects to be funded and establishes the subscription rate and the annual budget; in short, the Trustees act on behalf of AWWARF's members and subscribers to ensure that the program serves local interests efficiently and cost-effectively.

AWWARF's annual research agenda is developed through an elaborate representative process of consultation with members, subscribers, and working professionals. A Research Advisory Council composed of 18 top professionals in various specialties sifts through hundreds of suggestions and ideas to identify the high-priority, nonduplicative topics that will be most widely useful throughout the industry. From this synthesis and under the umbrella of the Five Year Research Plan, a list of specific project recommendations is presented to the Board each January for final selection.

Logically, the focus of the Foundation's program is the practical, operational needs of local water utilities. Over the past five years, approximately 95 percent of the Foundation's research program has been directed at "applied" studies. It is expected that the Board's allocation of funding to "basic" research will increase to 10 percent of the total funding effort over the next five-year period.

Implementation and Evaluation

AWWARF does not conduct its own research; it is carried out by local water utilities, universities, consulting engineers and other organizations — often by combinations of such agencies working together. AWWARF issues Requests for Proposals (RFPs) and potential researchers submit competitive bids; not competing as to low price but as to the quality of the research design and other factors that strengthen the probability of sound results.

The funding program is not restricted to United States researchers and, in fact, AWWARF has received a number of proposal from Canadian organizations and is funding one study with the City of Edmonton and University of Alberta.

Each project is assigned a Project Advisory Committee (PAC), a trio of experts in the specific area being studied. The PAC helps to write the RFP, evaluates the proposals, selects the contractor, and monitors the project throughout its implementation. About 200 engineers and scientists serve the Foundation as a volunteer cadre of advisors and peer reviewers.

Project Reports

The research reports completed by the Foundation are shown on the last page of a publication entitled "Research Foundation Projects; a Summary". Four of the documents - Activated Carbon in Drinking Water Technology, Occurrence and Removal of Volatile Organic Chemicals From Drinking Water, Internal Corrosion of Water Distribution Systems, and Identification and Treatment of Tastes and Odors in Drinking Water - were produced jointly by AWWARF and, respectively, KIWA (GAC and VOC), the Engler-Bunte Institute and Lyonnaise des Eaux. These reports deserve special mention because of the unique way they were produced and the comprehensiveness of the coverage for the four topics.

All of the reports combine European and American practice and experience into an integrated text which is designed for engineers, utility managers and experienced water professionals who need a practical guide. They have been produced in such a manner and style so that the reader can easily obtain information and references on any specific problem or can become acquainted with the general theory and practice.

These cooperative efforts between two research organizations required an average of two years to complete and were undertaken with the collective belief that such a publication would be an extremely useful document for the water supply profession throughout the world. In the latter two instances, the reports were used as the texts for a Sunday Seminar staged at AWWA Conferences. AWWARF and KIWA are currently collaborating on a "Sludge Manual" that is scheduled for completion in early 1989.

While the above reports are general references or state-of-the-art documents, most of the publications resulting from the Foundation's support are the complete reports of the research study. Many of the researchers utilize the comprehensive report as a basis for submitting an article to a peer-reviewed Journal like JAWWA. Because of a cooperative marketing arrangement with AWWA, all of the AWWARF's research projects can be ordered through AWWA's world-wide distribution network.

Active Agenda

The "Research Foundation Projects, A Summary" contains a one paragraph description of every project currently sponsored by the Research Foundation. In the six years between 1983 and 1988, the following general statistics describes AWWARF's research agenda:

- Eight percent of the number of projects are classified as technology transfer with the remaining ninety-two percent considered to be "hard" research studies;
- Research on water treatment technology consumed forty-four percent of AWWARF's external research budget;
- Research on distribution systems and monitoring/analysis developments accounted for, respectively, fourteen and twelve percent of the "hard" research funding;
- Fifty percent of the research budget was directed at regulatory issues involving the water utilities in the U.S. and Canada; and
- The funding directed at unsolicited projects amounted to fifteen percent with the remaining 85 percent allocated to problems identified and selected through the AWWARF planning process.

In 1987 AWWARF took its first steps into the toxicological research arena by sponsoring evaluative studies of the health effects of proposed U.S. drinking water standards. The primary purpose of this effort is to provide the water industry with a credible presence within this critical step of the regulatory development process and to ensure that the best scientific judgment is being utilized for standards setting. The program activities will be refined as AWWARF becomes more sensitized to the needs of the industry and more knowledgeable of the intricacies of toxicological research.

Technology transfer is a major activity of the Research Foundation. There is no point in conducting research if its results are not communicated to potential users. AWWARF uses its own monthly and quarterly publications to keep members and subscribers informed. AWWA publications and technical conferences are employed to reach a wider industry audience. In 1988, as more projects are completed, the Foundation intends to implement an even more vigorous program of outreach activities. For instance, AWWARF has produced a number of technical videotapes describing the results of a series of research studies on the same topical area. The videos on Giardia and "Colilert" are an example of this approach. AWWARF has also developed a number of topical seminars for presentation throughout the United States; they were successful in getting the researcher and practitioners together to discuss the theory and application of the work. The objective of the entire effort is to facilitate local application of the research results by subscribing utilities.

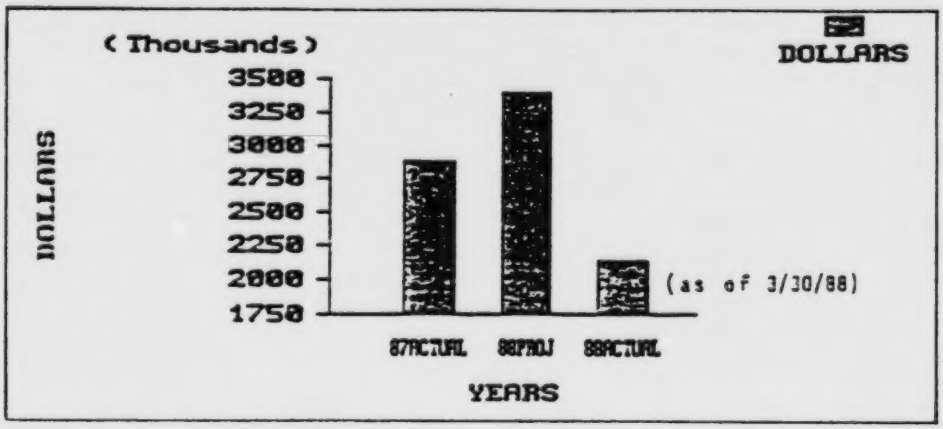
Over the past year, the Foundation has extended and improved its cooperation with other organizations. The primary purpose of this has been to establish contacts within the research community, avoid duplicative effort, develop collaborative programs, and enhance the recognition and credibility of the Foundation. The Foundation has a long-standing relationship with EPA and the water research organizations in Holland, Germany, France, and England. The Gas Research Institute, Electric Power Research Institute, American Gas Association, American Public Works Association, the Canadian Water and Wastewater Association, the Water Research Center of the United Kingdom, and WPCF are cooperating in the production of an infrastructure workshop. This will be the first time that utilities from the drinking water, wastewater, electric and gas industries will meet to exchange information and discuss an integrated approach to underground utility management and collaborative research.

Subscription Program

The 1987 subscription year ended September 30, 1987 with 228 subscribing utilities providing more than $2.8 million to the research subscription program. As the 1988 subscription year began on October 1, 1987, the 1988 subscription income was projected to be $3.4 million from 270 utilities. (The following graph shows the actual and projected subscription income for 1987 and 1988). There are also about 4000 additional organizations and companies which pay about $400,000 in membership dues annually.

Recruitment and retention of subscribers continues to receive a high priority within the Foundation's staff. During the past year attention has been focused on utility briefings and visits to individual utilities as the most effective recruitment method; presentations at Section meetings continue to be an important promotional tool of the Foundation. A four-page, four-colour brochure describing the Foundation and its research program was published during the past year.

SUBSCRIPTION INCOME - 1987 & 1988



Doubling the research program in one year, as was done in the last twelve months, doubles the potential return for every utility subscriber, with no increase in the individual utility's annual payment. Cooperative research pays dividends!

Future Plans

Utilizing a comprehensive developmental and review process, AWWARF has developed a Five Year Research Plan to serve as the program's framework in the upcoming years. The current plan identifies 125 priority project needs under 19 major goals which have a collective funding demand of an estimated $20 million. The plan embraces the full range of water supply operations including development and maintenance of water resources, treatment technologies, water quality issues, storage and distribution system operations, toxicological studies, monitoring and analytical development work, utility planning, and management activities.

The total research need is beyond the current and projected income of AWWARF requiring a rationale for setting priorities and selecting specific research projects. During the next five years, AWWARF's program will be guided chiefly by the following criteria:

- o research that will help water utilities respond to proposed drinking water regulations;
- o cost-reducing approaches to treatment and system operations;
- o practical assistance in dealing with distribution system problems, chiefly corrosion, water quality and rehabilitation;
- o health effects studies and activities to enhance industry contributions to the regulatory process; and
- o development of water quality monitoring and analytical techniques to improve accuracy and reduce time and cost requirements.

Summary

During the past twelve months the Research Foundation has advanced along all major programmatic fronts — subscriptions have increased, technology transfer activities have been enhanced, research projects have improved in both scope and number, and membership services have escalated. The past year brought an unprecedented amount of growth in terms of income to the Research Foundation and the organization responded in a very positive manner. The Foundation demonstrated conclusively that operational systems are in place to efficiently implement a major research program. And that capability is being recognized — all categorical groups within the industry, the scientific community, the federal government, and the international community have hailed the emergence of a centralized research program within the North American water supply industry.

USE OF PEAT IN THE REMOVAL OF OIL FROM PRODUCED WATERS

T. Viraraghavan and G.N. Mathavan
Faculty of Engineering
University of Regina

INTRODUCTION

The utilization of peat for treatment of oil-contaminated wastewaters is gaining attention as a simple, economical means of environmental protection. D'Hennezel and Coupal (1) found peat effective in the removal of oil from oil-in-water emulsions. They found that peat adsorbed up to eight times its weight of oil. Ekman and Asplund (2) reported that peat rendered hydrophobic by heat treatment compared very favorably with other oil-sorbing agents made of plastic, mineral wood, volcanic glass, and wood hydrolysis waste. Smith and Mark (3) indicated that both dried Irish peat and sulfuric acid-treated Michigan peat were found to remove 90% of oil from water by coalescence. The only limitation was the leaching of peat under alkaline conditions. Asplund et al. (4) designed a fixed bed peat filtration system for the treatment of oil-in-water emulsions of low stability. Viraraghavan and Mathavan (5) investigated the potential of using peat in treating various oil-in-water dispersions such as standard mineral oil, Midale crude oil, cutting oil and refinery effluent and concluded that peat is capable of removing up to 90% of oil from these oil-in-water dispersions.

In recent years, steam flooding which uses continuous steam injection for enhanced oil recovery has led the petroleum industry to demand more and more oil-free water. The formation water and condensed steam, which is produced along with the oil, after initial phase separation, is referred to as produced water. Often this water occurs as part of a stable oil/water/mineral emulsion from in-situ recovery operations. The characteristics of produced water very from site to site. The temperature of produced water, which is a consideration in the treatment process is typically in the range of 65-82^{o}C and the emulsified oil concentration after conventional gravity separation normally ranges from 50 to 400 mg L^{-1}. The ratio of oil to produced water varies from 1:2 to 1:10 (6). If produced water is to be used as once-through boiler-feed water, essentially all oil, hardness, suspended solids and silica must be removed. Re-injection requires only oil removal. In addition to this in-situ recycle, excess produced water will have to discharged in accordance with the stringent environmental discharge regulations. For recycle and discharge requirements, generally oil concentrations ranging from 1 to 30 mg L^{-1} are required. Therefore, the petroleum industry is hard pressed for an efficient and economical treatment method of the produced water (6). This paper is confined to the use of horticultural peat in the removal of oil from produced waters.

Objectives and Scope of the Study

The basic objective of the study was to investigate the potential of horticultural peat produced by Carrot River Plant of Saskatchewan Minerals in the removal of oil from produced waters. The scope of the investigation included characterizations of the peat and the produced water and batch studies to evaluate adsorption potential of the peat. Column studies were conducted to assess the adsorption capacity of the peat under dynamic conditions.

MATERIALS AND METHODS

The sphagnum peat moss used in the experiments was horticultural peat produced by the Carrot River Plant of Saskatchewan Minerals. The peat was characterized for particle size range, pH,

moisture, sand, ash and organic matter content, grain size analysis, and oil holding capacity. Produced waters used in the study were obtained from Saskatchewan sites through the Saskatchewan Research Council (Petroleum Division). Two different samples (one with high salinity and low oil concentrations and the other sample with low salinity and high oil concentration) were used in the studies. In both cases, the floating oil was separated and the emulsified sample was used in the experiments. Produced waters were characterized for salinity, conductivity, total solids, total carbon, pH, and oil content.

The concentrations of oil in the emulsions were determined by infrared spectroscopy using a Perkin Elmer, FT-IR spectrophotometer, Model 1600. Detailed discussions on the selection of the method and choice of the solvent are available elsewhere (7,8 and 9). The oily materials were extracted from the produced waters with carbon tetrachloride and the scanning was done from wave number 2700 cm^{-1} to 3100 cm^{-1} to draw the baseline absorbances. The net absorbances of the extracted sample at wave number 2860 and 2930 cm^{-1} were used to calculate the total concentration of the oily materials (10,11 and 12). Midale crude oil was used to obtain the basic calibration chart.

Batch kinetic and adsorption studies were conducted using a jar test apparatus at room temperature (approximately 21°C). Washed and air-dried peat in weights of 1g, 0.5g and 0.1g were mixed with 200 mL of the emulsion at 60 rpm to determine the equilibrium time. Six representative weights of peat in the weight range of 50 mg to 500 mg were mixed at 60 rpm with 200 mL of emulsion up to the equilibrium time determined from the earlier study to ascertain the adsorption potential of the peat.

In these experiments, the mixture of peat and oil emulsions were to be filtered only using glass wool, as the use of regular filter paper would also filter out the oil droplets remaining in the system after mixing. Some peat particles drain through the glass wool filters and leach during extraction with carbon tetrachloride. This necessitated the determination of correction factors for the leaching of drained-peat with carbon tetrachloride. Since peat in carbon tetrachloride produces absorbance at the same wave number as that of oil (2700-3100 cm^{-1}), it was possible to estimate the leaching of the drained peat as oil concentration in mgL^{-1} using the following procedure. All the oil from the produced waters was completely removed using carbon tetrachloride extractions. The oil-removed dispersions were then used with 50-500 mg of peat as per original isotherm procedures. Thus the extracted sample produced absorbances caused by the contact of drained-peat with carbon tetrachloride as mgL^{-1} of oil. Thus the oil-removed dispersions with peat and carbon tetrachloride would mainly indicate the interference of drained peat and other chemicals that were present in the produced waters. A correlation between the drained-peat and the interference as mgL^{-1} of oil was established through different weight fractions of peat for the produced water. These corrections were then applied before performing isotherm analyses. The correction for leaching of drained peat was necessitated only in batch kinetic studies. In the case of column studies, these corrections were not necessary as no peat fractions were drained into the effluent to cause interference with carbon tetrachloride extractions.

Column studies were conducted in a 100 mm diameter 600 mm long case acrylic pipe. A 300 mm depth peat bed was used in the experiments. The peat bed was supported at the bottom using 50 mm gravel packing over a circular perforated horizontal acrylic plate. A 25 mm thick gravel layer was placed on top of the peat to prevent erosion of the medium from the falling droplets.

The produced waters were kept in a feed tank where the emulsions were continuously mixed using 1/100 HP, 5000 rpm Greiner motor to maintain the homogeneity of the emulsion being fed. From this feed tank, the emulsion was pumped and fed into the column at a flow rate of 12 and 48 mL

min^{-1} in down-flow mode using motomatic motor generator with standard servodyne speed controller. The experiments were conducted continuously with an eight hour run. 200 mL of influent and effluent samples were collected and extracted with carbon tetrachloride to measure the concentration of oil. The effluents from columns were monitored for oil concentration every one hour. Parameters such as total carbon, total solids, salinity, and conductivity were measured at the end of the 4th and 8th hour of the run.

RESULTS AND DISCUSSION

The characteristics of the horticultural peat are presented in Table 1. When peat particles are placed in an oil dispersion and the slurry is agitated or mixed to give adequate contact, the adsorption of the oil occurs. The oil concentration will decrease from an initial concentration to an equilibrium value, if the contact time is sufficient. This equilibrium time was found to be less than 2 hours for the produced water sample as shown in Figure 1. The leaching of drained peat with carbon tetrachloride for the produced water is presented in Figure 2.

TABLE 1
Characteristics of Horticultural Peat

S.No.	Characteristics	Value	Test Method
1	Particle size range		ASTM D2977-71
	(a) Foreign matter	0	
	(b) Coarse fibre (>2.36 mm)	14.1 %	
	(c) Medium fibre (2.36 to 0.85 mm)	26.1 %	
	(d) Fines (dia <0.85 mm)	59.8 %	
2	pH at 21°C		ASTM D2976-71
	(a) in distilled water	6.0	
	(b) in $CaCl_2$	5.5	
3	Moisture Content		ASTM D2974-741
	(a) Method I	50-70 %	
	(b) Method II (at equilibrium temp 21°C)	58.60 %	
4	Sand content	2.6 %	ASTM D2975-71
5	Ash content	4.8 %	ASTM D2974-71
6	Organic matter content	37.5 %	ASTM D2974-71
7	Grain size analysis		ASTM D 421-58 & ASTM D 422-63
	(a) Coefficient of uniformity $[D_{60}/D_{10}]$	3.33-4.4	
	(b) Coefficient of concavity $[D_{30}]^2/D_{60}xD_{10}]$	0.99-1.66	
	(c) Effective size	0.15-0.24 mm	
8	Oil holding capacity	7.5-7.8	ASTM D1483-60

FIGURE 1
Equilibrium Time for Adsorption of Oil from Produced Water by Peat

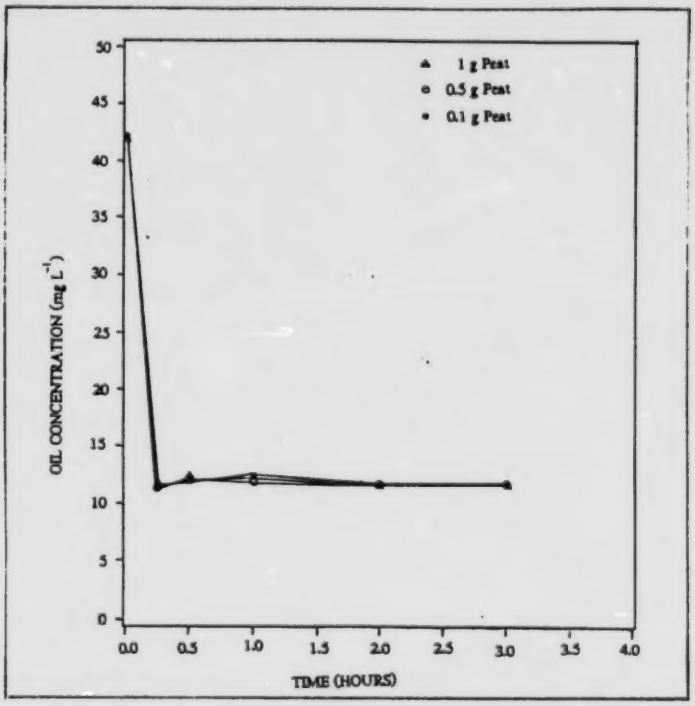
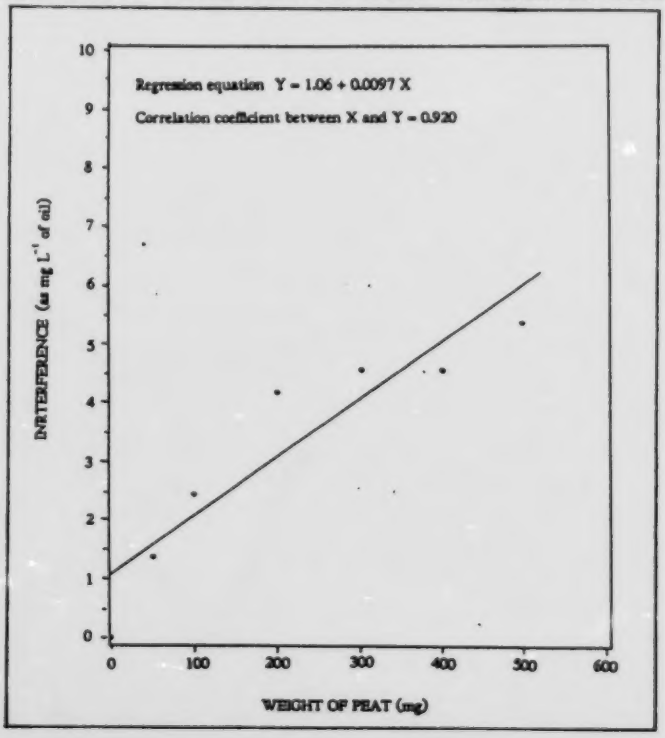


FIGURE 2
Interference of Drained-Peat with Carbon Tetrachloride Solution



Positive adsorption in a solid-liquid system results in the removal of solutes from solution and their concentration at the surface of the solid, to such time as the concentration of the solute remaining in solution is in a dynamic equilibrium with that at the surface. At this position of equilibrium, there is a defined distribution of solute adsorbed (x) per unit weight of the adsorbent (m). Most mathematical expressions describing adsorption, attempt to relate this ratio to various other parameters involved in the process. The most common forms of adsorption equations are the Langmuir, the Freundlich and the Brunauer, Emmett, and Teller (BET) models. A detailed discussion on these models is presented elsewhere (13). The Langmuir and the Freundlich models are valid for single-layer adsorption representing chemisorption. The BET model represents isotherms reflecting apparent multi-layer physical adsorption (13 and 14). These models are useful in quantifying the rate of adsorption, the equilibrium capacities and therefore aid in designing an adsorption column. They also provide enough information to assess the initial potential of the adsorbent for the removal of a particular pollutant; they do also help in examining the relative adsorption potential of various adsorbents in respect of removal of any particular pollutant in solution.

From the isotherm analyses, it was found that adsorption of oil from produced waters into peat followed the Langmuir and Freundlich isotherms (Figures 3 and 4). This indicates that this adsorption process is of a simple, monolayer type. The investigations conducted by the same authors on emulsions of standard mineral oil, Midale crude oil, cutting oil and refinery effluent did not follow the Langmuir and the Freundlich isotherms but generally followed the BET isotherm (5). It is likely that the presence of high concentrations of dissolved solids and salinity in the produced water may be one of the factors responsible for its divergent behaviour. The t-test and the F-test, the statistical parameters for a goodness of fit, were satisfied for the calculated and the table values at 5% significant level. The regression equations obtained, and the relevant statistical parameters are presented in Table 2.

FIGURE 3

Langmuir Isotherm for the Adsorption of Oil from Produced Water by Peat

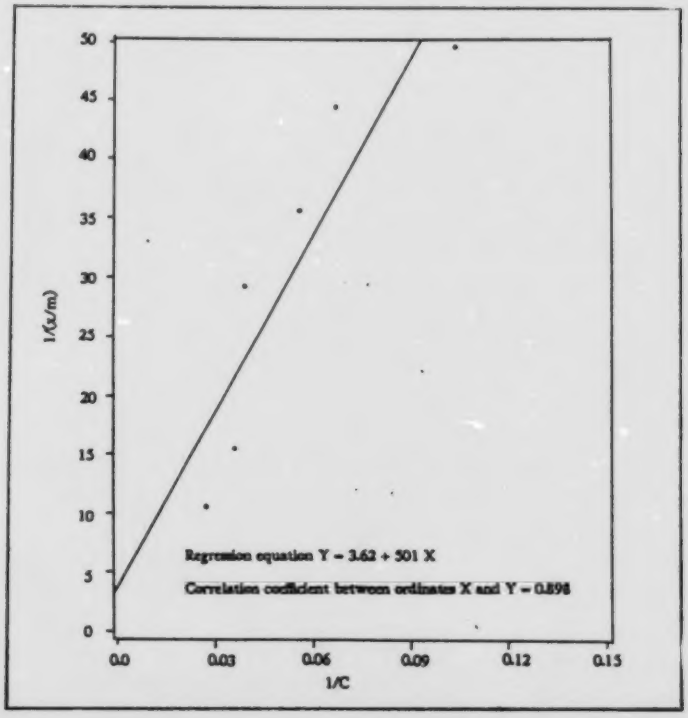


FIGURE 4

Freundlich Isotherm for the Adsorption of Oil from Produced Water by Peat

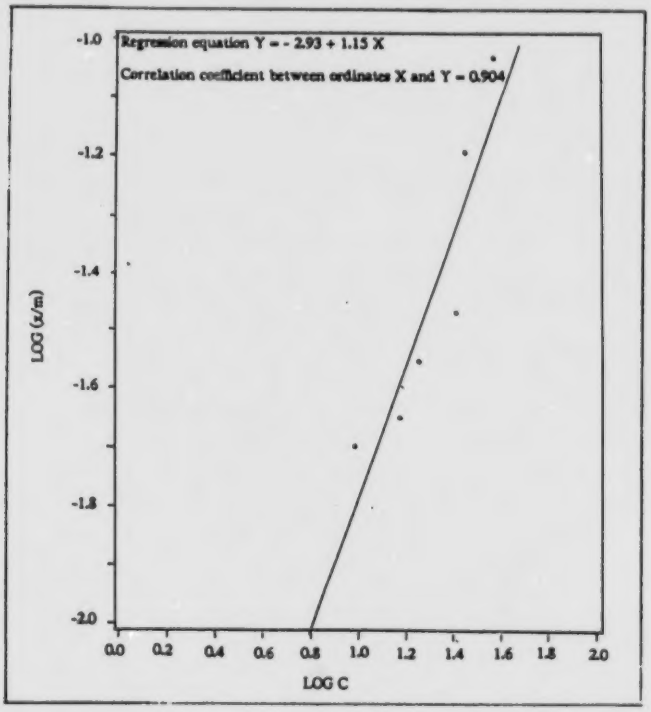


TABLE 2

Statistical Analyses for the Langmuir and the Freundlich Isotherm Equations

S. NO	Isotherm	Regression Equation	Correlation Coefficient (r)	Standard Deviation (Sy)	t_c^*	F_c^*
1.	Langmuir	Y = 3.62 + 501 X	0.9	7.65	4.08	16.67
2.	Freundlich	log Y = −2.93 + 1.15 log X	0.904	0.127	4.24	17.98

*t_c and F_c are calculated values of t and F
$t_{0.05}$ = table value at 5% significance level = 2.776
$F_{0.05}$ = table value at 5% significance level = 7.71

The influent and effluent characteristics of the two samples of the produced water used in the column studies under two different flow rates of 12 and 48 mL min^{-1} (2.13 and 8.52 md^{-1}) for an eight hour run are presented in tables 3 and 4 respectively. The average oil removal efficiency in both the cases exceeded 80% irrespective of influent characteristics and flow rates. Figure 5 shows the oil concentrations for the two samples for a continuous period of 8 hours.

TABLE 3
Summary of Column Test Results
(Sample 1; flow rate = 12 mL min^{-1})

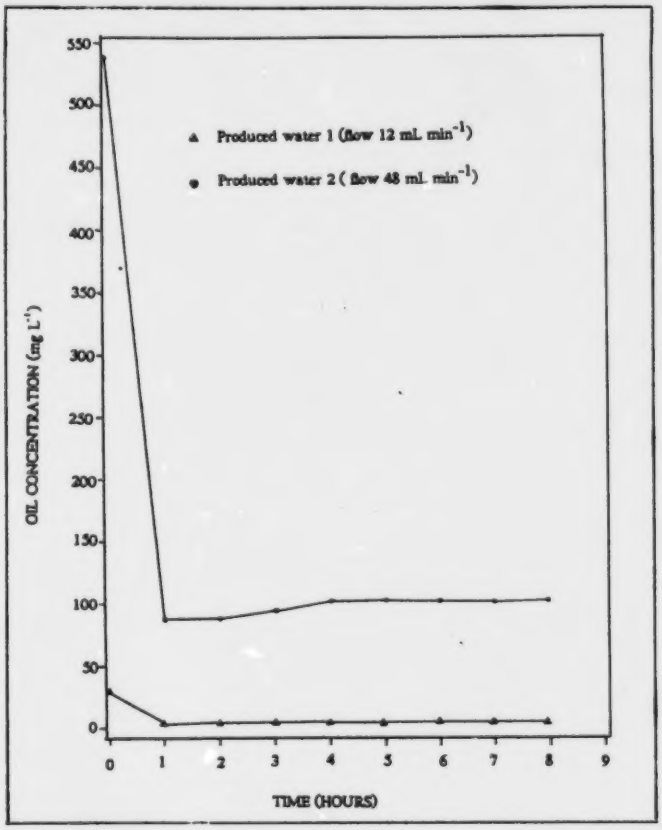
S. No	Description	Influent	Effluent			Removal Efficiency		
			Average for 8 hours	4th hour value	8th hour value	Average for 8 hours	4th hour value	8th hour value
1	Salinity (g L^{-1})	50	41.5	41	42	17	18	16
2	Conductivity (μ mho/cm)	72000	61500	61000	62000	14.5	15	14
3	Total Solids (mg L^{-1})	58530	102408	101213	103602	-74.9	-72.9	-77.0
4	Suspended Solids (mg L^{-1})	94	2.5	2.6	2.4	97.3	97.2	97.4
5	Dissolved Solids (mg L^{-1})	58436	102405	101210	103600	-75.2	-73.2	-77.3
6	Total carbon (mg L^{-1})	117.5	1836	1800	1872	Heavy	Leaching	
7	Total organic carbon (mg L^{-1})	87.5	1803	1800	1806	Heavy	Leaching	
8	Total inorganic carbon (mg L^{-1})	30.0	0	0	0	100	100	100
9	pH	6.7	-	6.0	6.5	-	-	-
10	Oil (mg L^{-1})	28.19	5.58	5.59	5.56	80.2	80.2	80.3

TABLE 4
Summary of Column Test Results
(Sample 2; flow rate = 48 mL min^{-1})

S. No	Description	Influent	Effluent			Removal Efficiency		
			Average for 8 hours	4th hour value	8th hour value	Average for 8 hours	4th hour value	8th hour value
1	Salinity (g L^{-1})	4	3.5	3.5	3.5	12.5	12.5	12.5
2	Conductivity (μ mho/cm)	65	60	60	60	7.6	7.6	7.6
3	Total solids (mg L^{-1})	14046	8859	8386	9332	36.9	40.3	33.6
4	Suspended Solids (mg L^{-1})	1270	103	22	184	91.9	98.3	85.5
5	Dissolved Solids (mg L^{-1})	12776	8756	8364	9148	31.5	34.5	28.4
6	Total carbon (mg L^{-1})	7525	4458	5135	3780	40.8	31.8	49.8
7	Total organic carbon (mg L^{-1})	7500	4425	5100	3750	41.0	32.0	50.0
8	Total inorganic carbon (mg L^{-1})	25	32.5	35	30	-	-	-
9	pH	6.9	-	6.0	6.6	-	-	-
10	Oil (mg L^{-1})	537.14	86.54	102.37	102.84	81.8	80.9	80.8

FIGURE 5

Effluent Oil Concentration in Column Tests



Design Applications

Most batch adsorption systems are operated on a fill-and-draw basis and are limited to small wastewater volumes. Only one reaction vessel may be required if all the wastewater is generated over an 8 to 12 hour period. Once the reaction vessel is filled with oily waters, peat can be added and the mixture can be agitated for a set time to enable the system to approach equilibrium. The vessel can then be drained and prepared to receive another load of wastes. If the wastewater is generated continuously, then two tanks may be used and alternated in the fill-and-treat modes. By applying either the Langmuir or the Freundlich isotherm models, it is possible to calculate the amount of peat required to reduce the oil from the produced waters to a desired concentration. The design capacity of the reaction vessel will reflect the minimum reaction time (equilibrium time) required and the volume of the wastewater to be treated.

The column studies conducted so far provided an initial assessment of the peat bed in treating produced waters under dynamic conditions.

CONCLUSIONS

The following conclusions are drawn on the experimental study:

1. The oil binding capacity of the horticultural peat was found to be 7.5 to 7.8 times its weight.

2. The kinetic study indicated that equilibrium was reached within 2 hours of contact between peat and produced waters.

3. The adsorption data generally followed the Langmuir and the Freundlich isotherms.

4. For the two different types of the produced waters investigated, an average oil removal efficiency of 80% was achieved in 8-hour run through a 300 mm peat bed irrespective of the flow rate, and the initial oil concentration.

ACKNOWLEDGEMENTS

This study was supported by an operating grant from the Natural Sciences and Engineering Research Council (NSERC) of Canada. The second author would like to thank the Faculty of Graduate Studies and Research for the financial aid received through a summer scholarship and teaching assistantship.

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TOXICITY AND STIMULATION IN ANAEROBIC DIGESTION

Jan A. Oleszkiewicz, Ph.D., P.Eng.
Associate Professor, Environmental Engineering
Department of Civil Engineering
University of Manitoba

INTRODUCTION

Anaerobic digester upsets are usually blamed on toxicity of heavy metals, sulfides or ammonia. Review of research work reveals, however, that some anaerobic cultures can tolerate very high total concentrations of these species. This presentation will address the issue of heavy metals as their role is often misunderstood and, as in the case of the iron family (Fe, Ni, Co), underestimated.

Metals play several important roles in anaerobic processes acting as: 1. microelements essential for various enzymatic reactions; 2. inhibitors and toxicants of the of the enzymatic reactions and thus the microbial biomass; 3. stimulants and promoters of bacterial aggregation; 4. inhibitors of sulfide toxicity.

Studies addressing variety of effects of metals on anaerobic processes show that numerous abiotic and process related factors interfere with the application of metal-effects data from pure cultures to industrial scale digesters (1). The net result is that precipitation, complexation, acclimation and population changes allow the digesters to operate at significantly higher (than presumed toxic level) total metal concentration or conversely call for much higher doses of metals as essential nutrients. Some of the salient issues involved in metals–anaerobic system interactions, including biotransformation, adaptation and engineering aspects of process control are addressed.

Heavy metals in anaerobic sludge digesters originate primarily from wastewater discharged from metal processing and metal finishing industries. Table 1 shows some of the sources and typical ranges of concentrations found in those effluents.

TABLE 1
Typical Concentrations of Some Metals in Industrial Effluents and Actual Concentrations in Sewage at the NEWPCC – Winnipeg

	INDUSTRIAL*		WINNIPEG SEWAGE**	
	Source	Concentration	Raw	Effluent
Cd	Electroplating, alloying	0–5000	0.004	0.002
Cu	Pickling, wire mills	0–800	0.15	0.04
Pb	Battery, explosives	0–850	0.08	0.02
Ni	Plating	0–3000	0.04	0.03
Zn	Smelting	0–50 000	0.5	0.2

* Patterson, 1981, ** Permut, 1988

Table 2 illustrates amounts found in the Winnipeg (2) sewage and in the resulting sewage sludge. Significant concentration of metals from sewage into sludge is typical and can result in very high levels in digester. The maximum levels, listed also in Table 2, are extremely high. Recently (3) it has been shown that the total concentration of metals in an anaerobic digester has little importance in predicting potential inhibition or stimulation.

TABLE 2

Concentration of Some Metals in Raw and Treated Sewage, Raw and Digested Sludge in Winnipeg NEWPCC, and Maxima cited in Literature

	SEWAGE*, mg/L		SEWAGE*, g/kg		MAXIMA
	Raw	Effluent	Raw	Digested	Digested** g/kg
Fe	4.0	0.7	15	20	153
Ni	0.04	0.03	0.06	0.07	3.5
Cr	0.38	0.07	1.2	1.6	99
Zn	0.46	0.23	1.2	1.7	28
Pb	0.08	0.02	0.4	0.6	26

*Permut, 1987 data **Sommers, 1977 and Kowal, 1985

STIMULATION BY HEAVY METALS

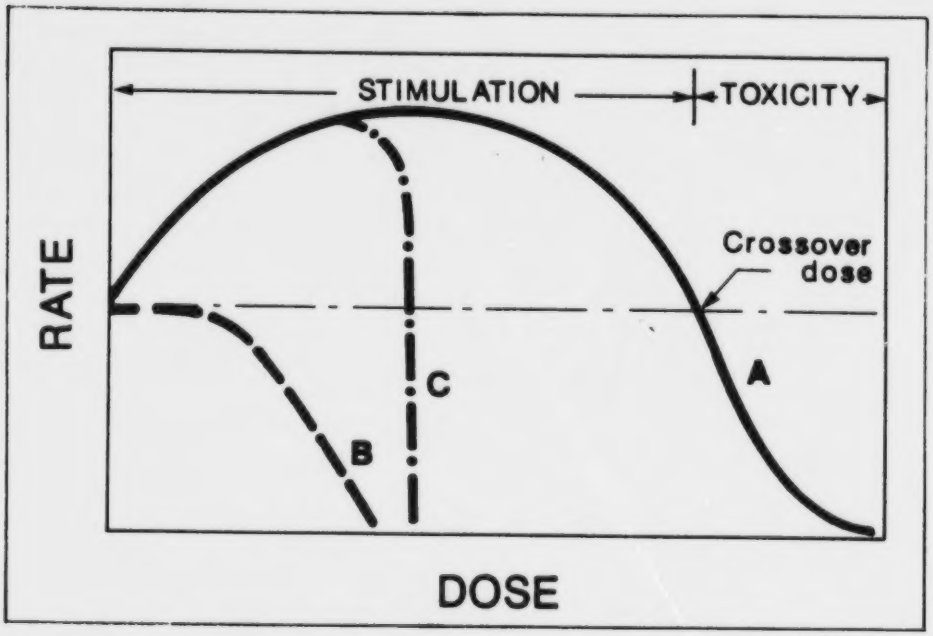
Some 30% of all enzymes have a metal as part of their structure, and this requires that metals be added for activity (3). Analysis of ten methanogenic (MPB) strains showed the following order of heavy metal composition in the cell FE>>ZN≥NI>Co=Mo>Cu>Mn(4) with the iron family considered the most important (Fe, Ni, Co). The importance of iron lies in its redox property and involvement in energy metabolism as cytochrome and ferredoxin. Nickel is essential to hydrogenase, catalyzing $H_2 \leftrightarrow 2H^+ + 2e^-$ conversion, and carbon monoxide dehydrogenase (CODH) which plays an essential role in acetogenic bacteria and in methanogens (5). Nickel plays a key role in factor F_{430} which is present in component C of CH_3-S-CoM methyl reductase system and is probably involved in terminal step of methanogenesis.

Cobalt is present in corrinoids. Cu and Zn are found in superoxide dismutase (SODM); Zn was found in some 70 enzymes (6). Recent studies (3) pointed to biological deficiency of Fe, Ni and Co in anaerobic systems in spite of measurable concentrations in sludge.

A generic diagram of methanogenesis versus metal concentration resembles a flattened bell shape curve for an essential metal: stimulatory at low concentration, non-toxic in mid-range and inhibitory at high concentrations. Non-essential metals exert no stimulation and are inhibitory at lower concentrations. In municipal digesters metals often exhibit an all or nothing response, i.e. sudden failure when toxic concentration is reached - Figure 1.

FIGURE 1

Effects of Metals on Anaerobic Digestion Rate



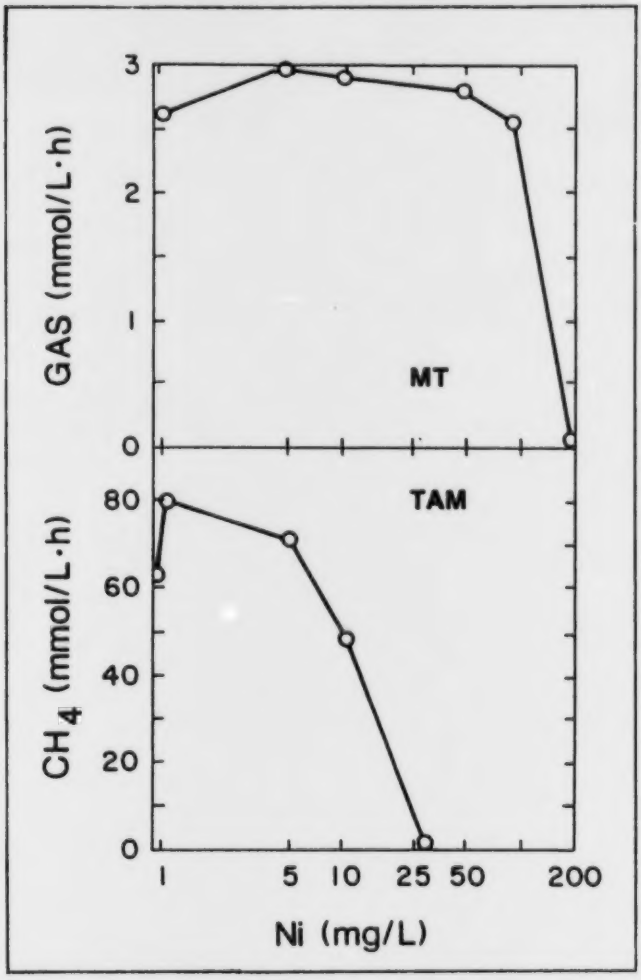
Examples of broad and narrow stimulation responses to nickel are presented in Figure 1 [adapted after Ahring and Westermann (7)]. Methanobacterium thermoautotrophicum (MT) had a peak at 5 mgL^{-1} and 50% inhibition at 130 mgL^{-1} Ni, while a thermophilic, acetate utilizing (TAM) methanogen tested in parallel had a peak stimulus at 1 mgL^{-1} and inhibition at only 10 mgL^{-1}. It follows that stimulation and toxicity thresholds in anaerobic reactors depend on the type and concentration of the metal and the dominant organism effected. In another study (8) a progressively increasing stimulation of a poultry waste digester gas production rate was accomplished with doses of .06, 0.6, 6 mgL^{-1} Ni in spite of appreciable trace concentration of this metal in feed.

Stimulatory effects of Fe^{+2} on sludge digestion have been shown at 10 mgL^{-1} (3) and 28 mgL^{-1} (9) with 1000% increase in acetate utilization rate (AUR). The soluble iron concentration necessary for stimulation was found to vary from 0.5 to 10 mgL^{-1} (3,9). Ten out of thirty tested municipal sludge digestors were found to respond to stimulation by individual or combined doses of Fe, Ni and Co (11). Cobalt at 2 mgL^{-1} stimulated AUR in conjunction with Fe and Ni (3), while only 0.19 mgL^{-1} Co in conjunction with traces of Ni, Mo and Se was sufficient to stimulate grass biomethanation (10).

Iron has been singled out as the most important metal in aggregation of biomass (necessary in sludge bed reactors) due to formation of sulfide precipitates (11) and the ability to tie up cysteine which may promote excretion of extracellular polymers thus promoting granulation (12).

FIGURE 2

Effects of Nickel on Two Methanogens:
MT – expressed as gas consumption;
TAM – expressed as CH_4 (Methane) generation



In a study of Portage La Prairie Industrial Park effluent treatability three parallel laboratory upflow anaerobic sludge bed (UASB) reactors were fed: R1 – unadulterated raw waste; R2 – waste with calcium and phosphate added; R3 – waste with 40 mgL^{-1} iron, 0.5 mgL^{-1} each of nickel and cobalt (13). Hard, granular sludge developed only in R3 which performed undisturbed through shock COD loads of 5 to 15 kg $m^{-3}d^{-1}$ and velocities of 1.5 to 6 mh^{-1}. Reactors R1 and R2 essentially lost sludge.

Based on the results of the pilot study (14) which preceded this work, which suggested the need for media to retain the sludge, one can attempt to make a hypothetical cost analysis of the two options: reactor operating without iron supplementation and fitted with random plastic media (anaerobic hybrid reactor); and reactor without the media, with continuous addition of metals.

The cost comparison, presented in Table 3, suggests that it is much more economical to maintain continuous supplementation of the raw wastes with Fe, Ni, Co mixture.

TABLE 3

Comparison of Two Reactor Options for Portage Industrial Park Effluent: Effects of Iron Supplementation to a 10t COD/d UASB Plant

ADD IRON:	2700 m^3/d, 40 mg/L Fe Cl_3
* OM	$ 65,000/a
* CC	$ 15,000
NO IRON:	MEDIA COST @ V = 11000 m^3
	\$100/m^3, 40% media
* CC	$440,000
* OM	$ 45,000/a
	(20% less gas at 1.63 kwh/m^3, 3.5 ¢/kwh)

TOXICITY OF HEAVY METALS

At high concentrations metals may exert toxic or inhibitory behaviour. Variety of mechanisms of inhibition, toxicity and detoxification are possible, depending on the sludge mix, reactor parameters, pH, alkalinity, presence of sulfides and other complexing species.

Discussion of toxicity has to be conducted with the understanding that measured total metal concentration is meaningless as microorganisms are <u>not at equilibrium</u> with the environment. Rates of uptake, not extracellular concentrations, determine the degree of toxicity (13).

Heavy metals exhibit most non-specific, noncompetitive inhibition in relation to substrate utilization or competitive inhibition in relation to another metal. The possible mechanisms of inhibition by metals include: substitution of metallic enzyme cofactors (prostethic group); combining with the sulfhydryl group (-SH) in cysteine or other thiol group-containing-enzymes; and, tight binding to acid groups in the side chains of the amino acids (exhibiting acid reaction such as aspartic or glutamic) in the polypeptide chain (15).

ACCLIMATION AND EFFECTS OF HRT/SRT

Addition of a slug of heavy metals results in decrease and cessation of methanogenic functions. The cessation is sudden for short solids residence time (SRT) reactors and gradual for longer SRT systems. The reactor is (reversibly) dormant and the length of dormancy (or lag) is proportional to the magnitude of the shock.

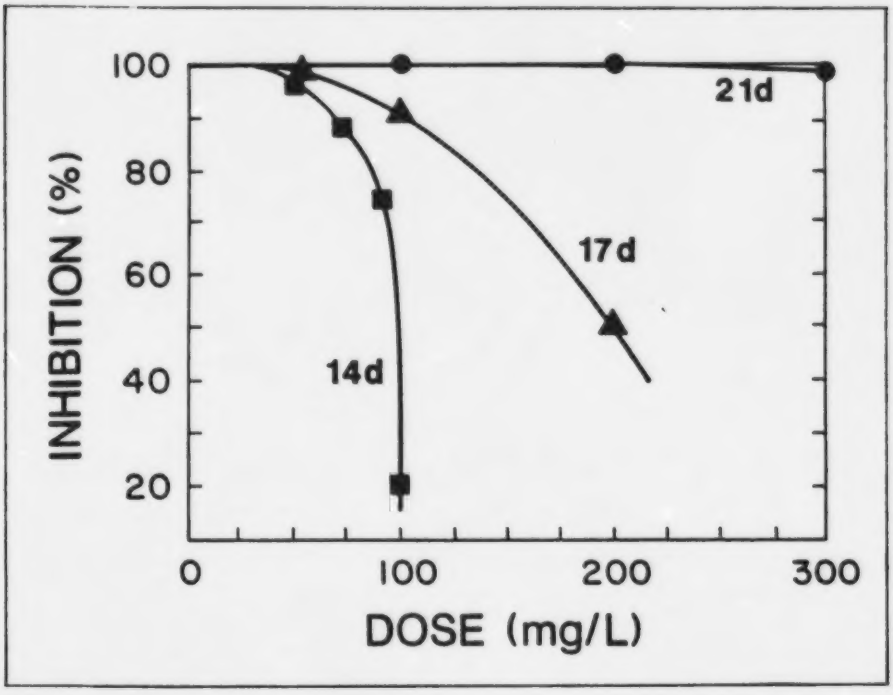
Gradual increase of concentration of a heavy metal may lead to acclimation. Acclimation allows for significant increase in concentration, often an order of magnitude above that found toxic in batch cultures. A generic term - acclimation - may encompass a variety of mechanisms. One is stimulation or turning on and expression of dormant genes. Other may involve: development of

intracellular defense mechanisms discussed above; transfer of plasmids; mutation [eg. caused by attachment of some metals to DNA]; and a gradual population shift. All are kinetic processes and as such overall acclimation is best conducted in continuous flow reactors, at sublethal chronic concentrations, or depending on HRT/SRT ratio, using short duration shock loads.

Heavy metals affect the growth rate and thus induce the requirement for longer minimum SRT [or HRT]. Data from an 8-week long sludge digestion study by Bailey et al. [16] can be presented as in Figure 3 indicating that up to 300 mgL^{-1} Cr[3+] was tolerated at HRT>21d. After prolonged acclimation another study has shown no adverse effects on sludge digestion at 30d HRT, at 1120 mgL^{-1}Cr [17]. Chromium is considered to be one of the least toxic non-essential metals in methanogenesis.

FIGURE 3

Effects of Hydraulic Residence Time on Tolerance of Various Doses of Chromium Cr[3+] by an Anaerobic Sludge Digester



Fixed film reactors offer long SRT and this is the best safeguard against metal toxicity [18]. Sluge are easily washed through and long solids residence time compensates for increased required min-SRT. Series of studies on nickel toxicity [18,20] have shown: little relation between acute response of unacclimated batch culture and response to both acute and chronic levels of Ni by an acclimated anaerobic biofilter, reversibility of toxicity at doses as high as 2400 mgL^{-1} Ni, provided contact time [HRT] was short [eg. 1h].

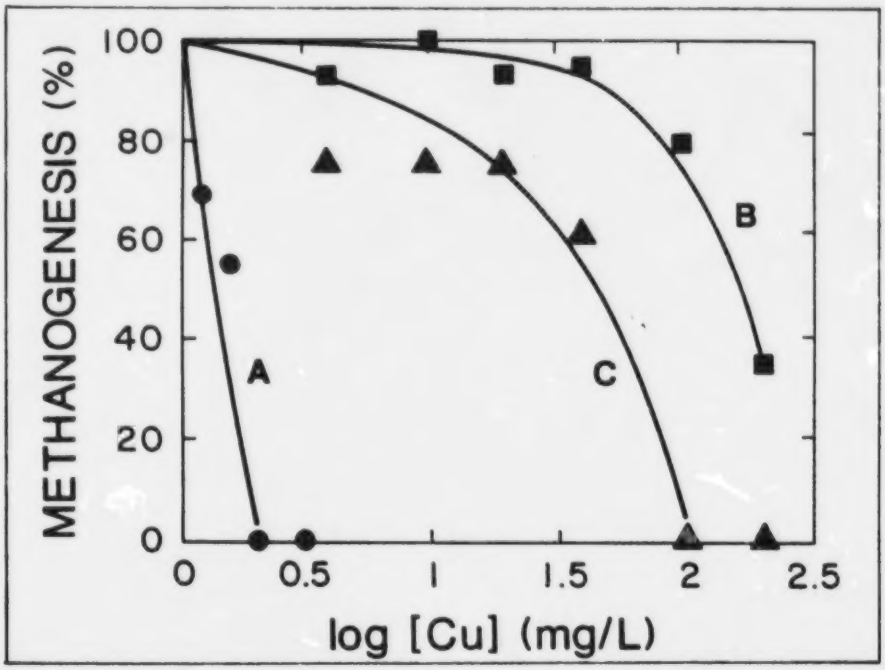
EFFECTS OF SLUDGE SOLIDS ON TOXICITY

Presence of sludge solids in the reactor offers tremendous abiotic surface to interact with the metallic ions introduced into the system. Studies of toxicity indicate the need to relate the dose of metals to the amount of solids, i.e. express it in mg M^+ (g dry solids)$^{-1}$ rather than mgL^{-1} (21).

Abiotic effects denote physico-chemical means, rather than effects of biological complexing and/or precipitation. Such protective effects were studied by Jarrell et al (19) who have measured inhibition of methanogenesis by zinc, nickel and copper, when incubated with a sterile (heat treated) sludge from two municipalities. Methanospirilum hungatei was incubated in HEPES buffer at pH = 6.5 (Curve A) and in heat treated municipal sludge (B) and (C) in Figure 4 (adapted from reference 19).

FIGURE 4

**Effects of Copper on Methanogenesis in: A. HEPES Buffer;
B. Sterile Sludge from Municipality B;
C. Sterile Sludge from Municipality C**



The study showed 50% inhibition at Cu concentration of 2.3 275 and 65 mgL^{-1}, respectively (Fig. 4, ref. 19 after Jarrell, et.al.). Comparable protection of pure cultures of MPB was offered by sterile sludge against Zn and Ni. The study exposed similar toxicity of Cu and Zn and pointed to 1000% differences in toxicity thresholds reported for the same nickel - methanogen system by different researchers (7,19) and cited a record resistance of Mb. formicicum to 15000 mgL^{-1} Ni in batch culture. These hugh differences in thresholds of toxicity observed for just one metal illustrate the complexity of factors responsible for bioavailability of metals during anaerobic digestion of such complex mixtures on sewage sludge.

CONCLUSIONS

1. Metals can stimulate, enhance agglomeration, precipitate nutrients and toxicants and inhibit anaerobic sludge digestion.

2. Concentration of heavy metals found stimulatory to one anaerobic organism may be inhibitory to another.

3. Total metal concentration is not a reliable value in predict stimulatory or inhibitory response.

4. Bioavailability of metals as nutrients depends on the nature of the soluble metal species (complex).

5. Metal speciation depends on physical, chemical and biological conditions in the digester and varies widely for different digesters.

6. Digester solids offer strong protection from metal overdose, often beyond published inhibition thresholds.

7. Importance of high solids content, high SRT and HRT in digesters cannot be over emphasized.

8. Biomass-metal interactions are so complex that the net effects must be determined experimentally.

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AUTOMATED WATER METER READING - BILLING SYSTEMS

R.K. Storozinski, P.Eng.
Town Engineer
Town of Dauphin

M.W. Anderson
Waterworks Division
United Westburne Industries

The Town of Dauphin currently has approximately 3250 water utility customers. All water sold is metered and the water meters are read and customers invoiced quarterly. The Town's water meter inventory is not specifically known, however, it is estimated that in 1982 it consisted of:

1. 10% Kent Meters
2. 60% Trident CIB Meters
3. 10% Trident Seal Meters
4. 20% Trident S Meters

Prior to 1982 the Town hired approximately 10-12 workers on an hourly basis to read the water meter system. Only 2 or 3 were repetitive readers and provided quality work. The percentage of meters read are estimated to be approximately 50%-60%. Some of the significant problems encountered with this system were:

1. Extremely low number of meters read consequently high estimated readings.

2. Complaints about incorrect readings or readings inserted without the meter being read.

3. Little attempt made by readers to obtain readings.

4. Questionable conduct of the readers while in the customer's homes.

5. High turn over in casual readers required frequent instruction.

6. Supervision of the casual workers scattered throughout town proved to be difficult.

7. Since so many readings were missed, office staff were constantly interrupted for approximately 2-3 weeks each quarter with phoned-in readings.

In mid 1983, the Town of Dauphin in an effort to rectify its current meter reading problems, contracted out its water meter reading. The contractor was able to obtain 4 or 5 competent workers (usually a family type of operation) who were able to improve the quality of quarterly readings. However, the number of estimated readings still remained relatively high.

In late 1983 the Council of the Town of Dauphin agreed to commence a program of conversion to remote reading equipment for the following reasons:

1. To raise the number of water meters read to a more acceptable level thus maximizing revenue.

2. To increase the accuracy of water meter readings thus minimizing customer complaints, meter checks and staff time in attending to complaints.

3. To minimize customer complaints about employee conduct while in residential homes obtaining meter readings.

Inquiries were made of various committees in Manitoba to determine whether or not they had similar problems and if so how they were resolved. It was found that several communities had or were in the process of converting to some form of remote reading devices because of similar problems in the meter reading system. The Town of Dauphin decided that a better meter reading system must be implemented and that in addition to resolving current problems it must be able to address future needs.

The Neptune Automated Reading Billing (ARB) system appeared to best address the Town's requirements and was selected for the following reasons:

- 90% of the Town's meters were manufactured by Neptune. Neptune Meters Ltd. advised the Town that conversion kits were available for all Neptune meters adapting them to the ARB system.

- the ARB system allowed for progressive conversion of the system. Initial meters could be read manually by using a reading/test unit. The system had capabilities of adapting to current computer systems using a magnetic tape cassette recorder and eventually could be converted to a future central meter reading system.

- the system provided easy coding of customer accounts within the remote receptacle.

- the system allowed direct reading of the meter register with no possibility of error between the meter register and the exterior receptacle.

- Metric conversion was actively promoted at the time. This was not an influencing factor on system selection but the Town of Dauphin decided to convert from the existing Imperial system of unit measurement to the Metric system.

The initial program involved conversion of water meters to the ARB system in homes and commercial buildings where readings were difficult to obtain, such as:

- both husband and wife were working or not home during normal working hours.

- meters were located in very inaccessible areas.

The next phase of the program was an orderly scheduled conversion of meters throughout the Town. The Town has provided from $5,000 to $10,000 annually for conversions. Since 1983 all new accounts are equipped with remote registers. Whenever meters are removed from test or repair/replacement the account is converted to the ARB system. In 1987 the average cost of converting Trident 8 meters was $55.00 (materials) plus $10.25 to $20.50 (labour). The labour cost will vary depending on the degree of difficulty in wiring in the remote receptacle. If the building is new, installing the wiring for the remote receptacle may take only a half hour. Homes with finished basements can take up to two hours to wire in order to conceal the wire or at least make it less noticeable. All work is done in consultation and in cooperation with the owner. No work is commenced until it has been reviewed with the owner and he/she is satisfied. To date no difficulties have been encountered. In addition to the installation/conversion cost, the only other costs incurred have been in the purchase of a coding/test unit. An initial unit was purchased in 1983 at a cost of $1023. An additional unit was purchased in 1987 at a cost of $753.

The results of the program to date have been a progressive increase in the number of water meters read to 78% for the first two quarters of 1988.

TABLE 1
Town of Dauphin
Water Meter Reading Data

Year	Meters Read (%)(1)
1980	(2)
1981	(2)
1982	(2)
1983	66
1984	68
1985	74
1986	74
1987	71
1988	78 (3)

Notes:
1. Percentages are based on the average for the four quarterly readings
2. No records available
3. Average of first two quarterly readings

TABLE 2
Water Meter Reading Costs

Year	Annual Cost
1980	$ 4451
1981	5415
1982	4954
1983	5773
1984	7170
1985	7307
1986	7282
1987	7283
1988	7400 estimated

The Town of Dauphin is now entering into its sixth year in the conversion program and is well satisfied with the route it has taken. Communities that are contemplating similar changes in the water metering system should be aware of three specific areas in the conversion program.

Converting homes with finished basements have proved to the most troublesome part of the program. Staff involved in the actual installation must display utmost consideration, courtesy and patience. They must recognize and appreciate that they are in and working on private property. Care must be taken not to damage building finishes, furniture or any of the customer's belongings. They must ensure that the utility customer is fully aware of what will be done in the conversion and not proceed until the customer is satisfied. If there is any doubt the worker should call his supervisor to discuss the matter with the customer. The

workers should ensure that all debris arising from the installation is removed and that the premises are in an equal or better state compared to when they commenced the work. It is recommended that the ARB installation work be assigned to a specific few workers who are personable and who can develop a good working system and good rapport with the public.

It should also be recognized that material deliveries may take several weeks; especially the conversion kits. Work should be planned well ahead to ensure minimum disruption in the homes. The exterior receptacles and wiring generally are readily available. The work can be done in two phases. Initially, the wiring and exterior receptacle can be installed. The actual meter conversion connection can be performed later and is usually a 10 minute installation.

Since conversion kits are only available for the Trident 8 Meters, all other meters must be taken out of service. Many of them are still in good working order and perfectly usable. No attempt has been made yet to determine if other communities would like to purchase them. If no market is available, the meters have no value other than scrap which is minimal.

The Town of Dauphin is the midst of computerization. Current priorities are in the area of tax roll, general ledger and job costing. The billing portion of the water utility has been fully computerized. There are no plans yet to commence water meter readings on a magnetic tape recorder. Keying in readings on computer currently is estimated to take a clerk approximately 18 hours (including interruptions) per quarter. The Engineering Department's preference will be to continue with meter conversions.

Dauphin's conversion of its water metering system to an automated billing reading system has proven to be a substantial improvement to the system. Complaints respecting readings have been reduced significantly. Office staff time required to attend to missed readings and conduct of the meter readers have virtually been eliminated. Scheduling the conversion over several years has resulted in no financial hardships to the utility system. Meter reading costs have remained constant for the past 5 years, office staff time has been reduced and customer response to the new system has been exceptionally favorable. The program is considered to be successful!

More specifically now, this is what the Neptune ARB system is all about:

Neptune has been known strictly for municipal cold water meters, but they also have a large range of precision engineered industrial products, some of which are used municipally, such as the Insertion Mag Meter in water treatment facilities.

The ARB system is really one of Resource Management. The focus is primarily in two areas; the first is Water Resource Revenue. In the majority of municipalities water generates the second largest revenue; only properly taxes rank higher. That's why it is essential to accurately measure water consumption. The second area is Human Resource. Meter reading and data capture systems increase productivity, decrease customer problems and ultimately increase the bottom line of the water revenue that has been generated.

Obviously to generate revenue, water usage must be measured. This water meter is an early version of the Standard Reading Register. Standard registers such as this have been providing accurate, reliable measurement for over 70 years.

The advantage of the Standard Reading Register is that it provides 100% reading integrity (when the meter reader gets to read it). You can then accurately bill the customer for water used.

The disadvantages are:

* Call Backs - revenue is not maximized when the meter reader has to make several calls before gaining access.
* Customer Service - some people do not want to let a stranger into the house.
* Estimated bills can cause customer problems and expense.

These problems waste productivity and cost money. Both take away from the bottom line of generated water revenue.

The next logical step was then to develop a meter which could be read from outside the house. The Self-Generating Pulser was developed to fill this need. First manufactured in 1966, the Self-Generating Pulser was based on the electro-magnetic technology of the time.

Simplified, Pulser Remote Meters work by having the waterflow turn a magnetic shaft between two copper coils. When the shaft has turned 350 degrees the attached spring snaps it back, generating an electro-magnetic pulse which is sent through the wire. The pulse reaches the remote register and the odometer advances on unit.

However, this type of technology has some vulnerabilities both inside and outside the house. Any reduction in component performance, interference with the wire or the remote register can cause the pulse to fail and not register, or to register intermittently. The meter reader will get a reading, but it will be incorrect and may not be discovered for several months or perhaps longer.

This may eventually result in a revenue problem, customer service problems, or both, leading to a situation where cash flow and bottom line revenue are hurt.

So the advantages of the Self-Generating Pulsers are:

* Meter reader doesn't need to the customer's premises.
* Remote reading eliminates estimated bills and call backs.

The disadvantages are:

* Reading errors due to the vulnerability of the electro-magnetic pulse in transmission and registration. Call back problems if the reading is incorrect.
* Manual reading and data entry problem - reading error, transpositions, etc.
* Any data capture system that relies on electro-magnetic pulse transmission is prone to the same problems of unreliable reads.

Advanced electronics are the technology of today and will be the technology of tomorrow. From radios to calculators, TV's to computers, electronic chips and circuit boards are the component base.

Today's Encoder Register employs this technology, utilizing an advanced silicone chip to provide a digital signal. When the Encoder Register was first introduced, it employed a 14-wire connection, but it proved inconvenient to install. Over the past years this was redesigned.

The modern Encoder version uses a standard 3-wire cable between the register and outside receptacle. The 3-wire system ties in perfectly with CMR (Central Meter Reading) technology.

The Encoder electronics work by having the reading gun send an electronic charge down the line to interrogate the register wheelbank directly. The exact position of the odometer wheelbank is identified electronically. The wheels have contact points on the side of them that change positions relative to the stationary circuit board as the wheel turns. The electronic charge completes its circle back up the wire, providing 100% reading integrity. The meter reader will always get the exact reading directly from the wheelbank. If there is any problem, the reader will get no reading at all, and will be aware immediately that a problem exists. He may even be able to solve the problem at the customer's premises.

So, the advantages of the Encoder Register are:

* 100% reading integrity - obtaining a 100% accurate read because the reading is being taken directly and electronically from the odometer of the register.
* Provides an electronic digital signal which is the basis for use with new, more cost efficient computerized reading systems.

What this means is that the Automated Reading and Billing System can maximize water revenues by:

* virtually eliminating costly rereads and estimated bills.
* eliminating entry errors.
* increasing meter reader productivity, which is especially important in growing municipalities.
* improving customer/utility relations by recognizing a problem immediately and solving it quickly.

All this means substantially increasing the bottom line revenue and providing better cash flow for the utility.

And finally, Automated Reading & Billing facilities use of advanced electronic reading systems, which will further reduce reading and billing cost.

AUTOMATED READING SYSTEMS

Encoder Register with Simple Reading Gun

* Simple reading gun that provides meter reading and six-digit identification number.
* 100% reading integrity, no synchronization problems with the outside reading and the reading register.

Hand-Held Electronic Data Capture Units with Encoder Registers

* Advanced data capture capability maximizes meter reading efficiency. This is basically a hand-held computer that replaces the old route book and guides the meter reader through the route. It electronically stores the readings that are taken automatically. Through computer interface, the reading information can be electronically transferred to the billing computer for the automatic production of water bills. This maximizes the efficiency of bill production operations and increases a utility's cash flow.

* Less expensive than competitive units.

Encoder Registers and Central Meter Reading

* Central Meter Reading is a system that allows a water, gas or electric utility (or all three) to accurately and automatically read meters from a central location using telephone or cable TV lines.

* The digital signal provided by the Encoder Register allows the meter to be read automatically over the telephone lines by a computer. Instead of the external receptacle, the meter is now wired to a meter interface unit which is installed in the customer's home. This unit is connected to the customer's telephone line and in this way a utility can read the water meter. Neptune has an installed base of approximately 20,000 Central Meter Reading Systems meters that are read in this manner.

CMR AUTOMATES	* Meter reading through electronic interface. * Provides constant access to consumption data. * Prevents lock-outs and call backs. * Speeds up the billing cycle. * Eliminates reading errors.
CMR SAVES MONEY	* Stabilizes future operating costs. * Reduces overhead and support costs. * Prevents costly rereads.
WHY CMR NOW?	* Rising meter reading costs * Deregulation of Bell Telephone * Penetration of cable TV * Conservation of management of natural resources * Technological advances

ARB "THE FOUNDATION"

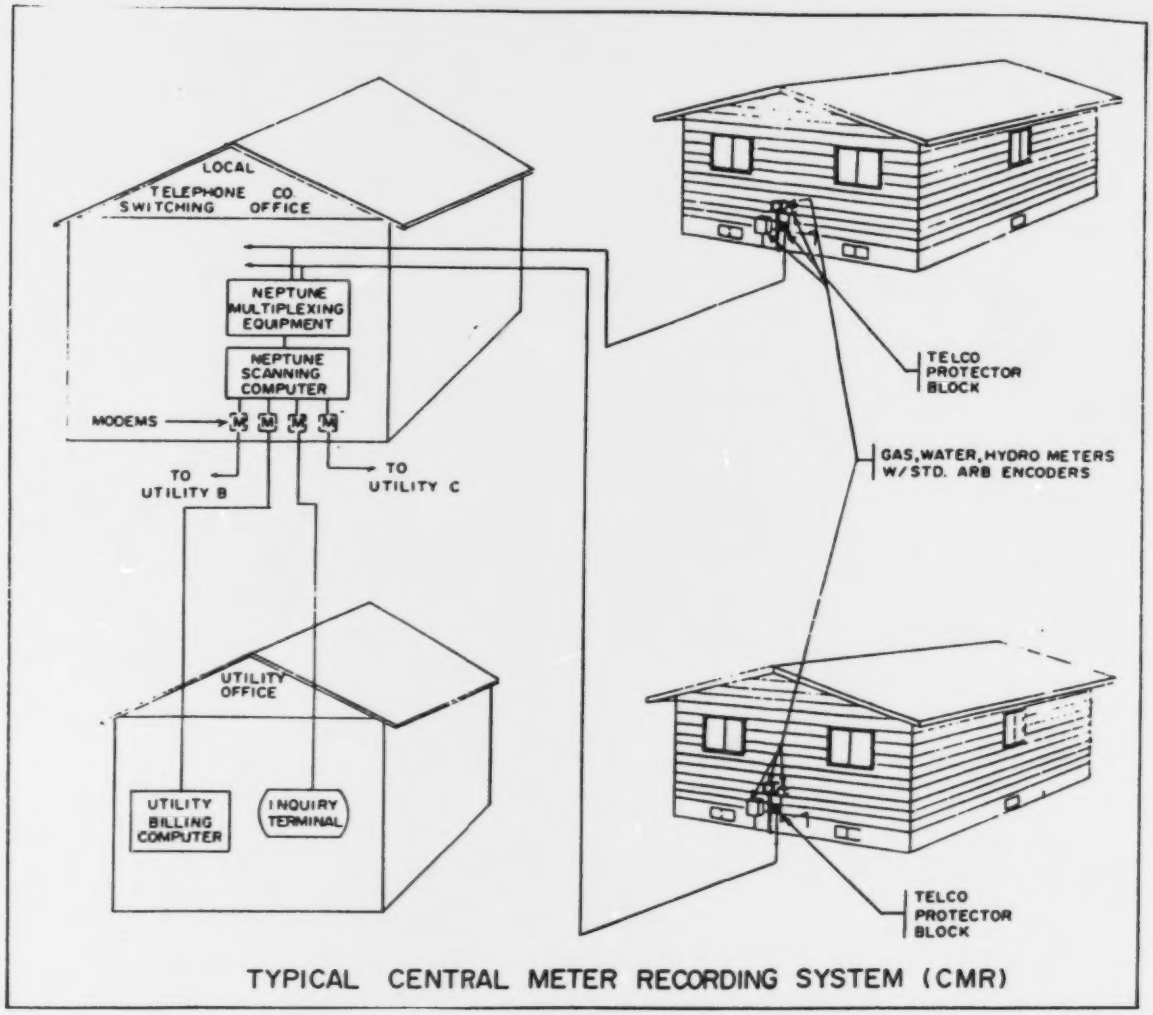
Summary Encoder Register Benefits

* 100% reading integrity. No synchronization problems.
* Uses modern technology, which provides cost-efficiency for both today and tomorrow.
* Compatible with today's hand-held data capture and tomorrow's CMR technology.
* Maximizes municipal revenues.

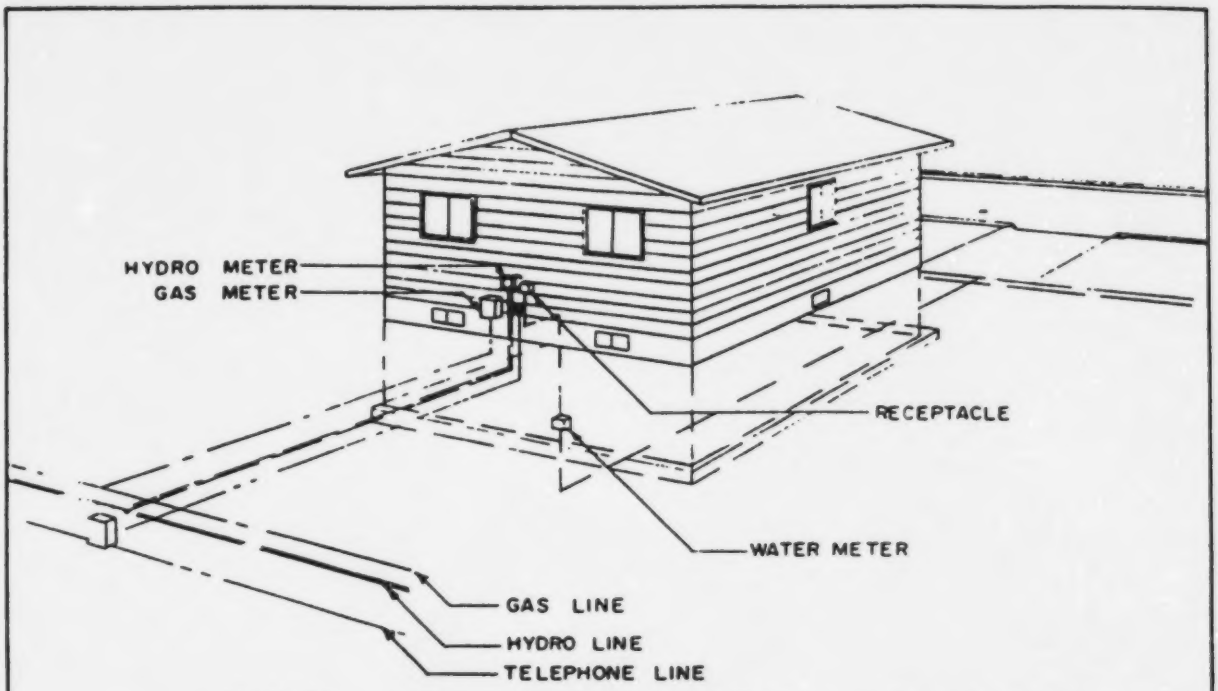
ACKNOWLEDGEMENTS

Eugene Mayuk
Town of Dauphin Plant Operations

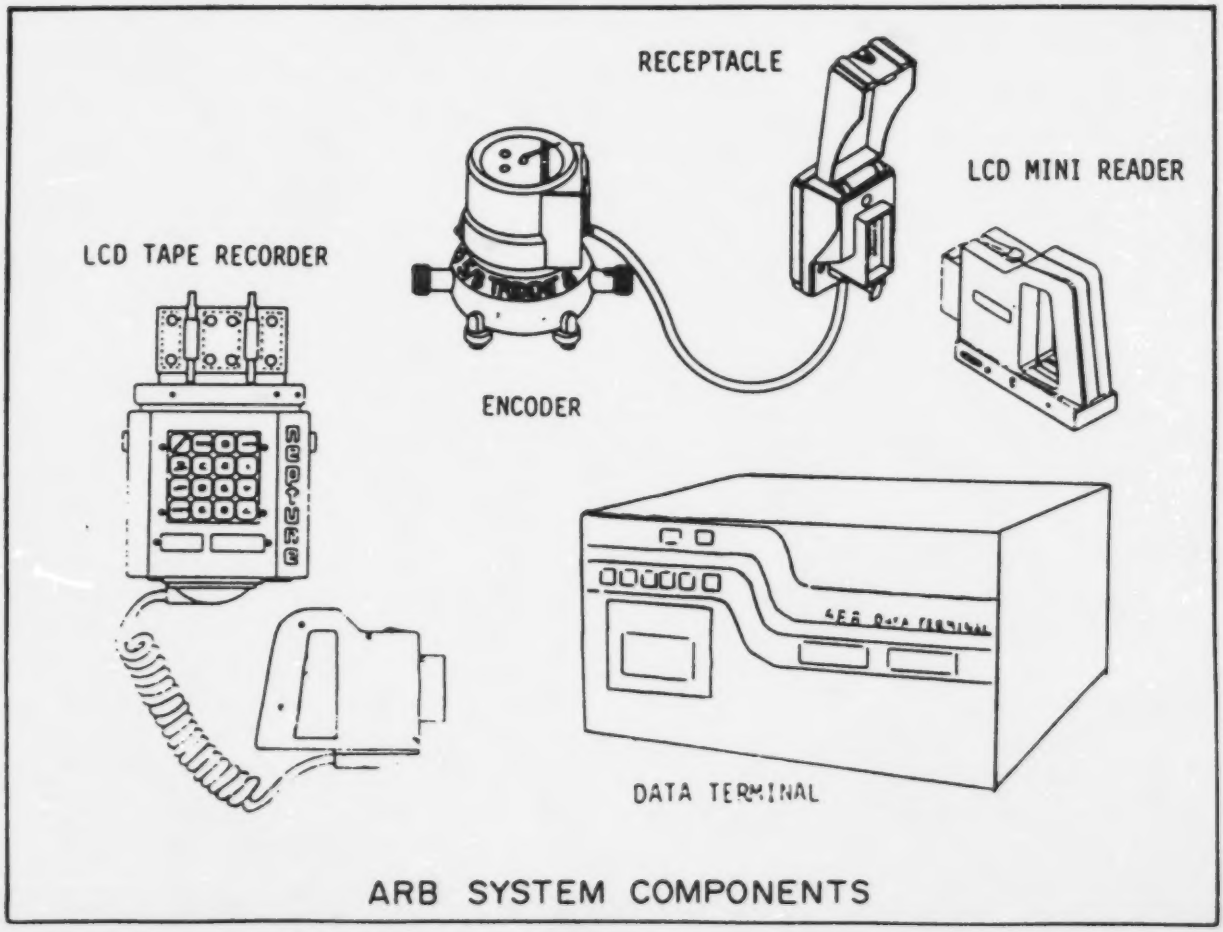
Barry Zaleski
Town of Dauphin Engineering Clerk



TYPICAL CENTRAL METER RECORDING SYSTEM (CMR)



TYPICAL ARB SYSTEM RESIDENTIAL INSTALLATION



ARB SYSTEM COMPONENTS

HISTORY OF TAPPING WATER MAINS

Presenter:
John McClure
Mueller Consultant

In the days prior to 1871, water distribution pipes were made from hollowed out logs, later of wire bound wooden staves and still later of cast iron.

The method of tapping for laterals and house service connections was pretty crude and was accomplished by drilling a hole in the pipe with a brace and bit and, while the water flowed from the hole, a crude corporation stop was pounded into the hole. If you were lucky, you were successful, if not, you got very wet, and probably the main would have to be shutdown depriving the area of water supply and fire protection.

The stop has a long tapered inlet, similar to that on a beer keg tap. The outlet has a stub, onto which the lead service pipe was wiped. This area, which is in a direct line with the inlet, is where the hammer blow was struck to drive it into the main.

It was during this era that Hieronymus Mueller, a gunsmith, arrived in Decatur, Illinois and became the town plumber whose duties included the tapping of water mains.

To indicate the inventive genius of the man, I would deviate from this topic by talking about the early days of the auto industry in America. About 1890, he imported from Germany, his native land, a Benz automobile and by 1897, he was granted U.S. patents on the variable speed transmission, steering gear and body suspension, water cooling radiator and two of his sons had patents on the earliest form of spark plugs and the make and break circuit used in distributors for modern cars.

In this Benz auto, now known as the Mueller/Benz auto, the first road race ever seen in North America was won by Mr. Mueller. The Mueller/Benz auto also entered the second auto race which had eleven contestants and came in second with only two cars completing the course.

In 1900, Mr. Mueller was badly burned in a tragic accident while working in one of five autos he had built and died as a result of burns.

Thus ended what might have been the Mueller Automobile Manufacturing Company.

In 1871, the City of Chicago offered a prize of $1,500.00 to anyone who could devise a better method of tapping water mains under pressure. In 1872, Mr. Mueller produced the first pressure controlled water main tapping machine in which the theory of drilling through a control valve was utilized and which theory is still in use today. Early photographs show the notched handle, the feed yoke, the upper chamber, the control valve and the necessary tools.

It didn't look like much, but it was a major breakthrough in the waterworks industry and thus launched the H. Mueller Manufacturing Company.

To utilize this machine, Mr. Mueller had to redesign the corporation stop which would be inserted in the main with the machine.

The first newly designed stops had an I.P. inlet thread, which, because of the 3/4" taper per foot, had a tendency to split the main as it was screwed into the main.

As a result, he increased the amount of taper to 1 3/4" taper per foot. The number of threads per inch remained the same and by doing so, he had more threads in contact with the pipe wall, by virtue of the longer hypotenuse of the angle, and a thicker, stronger body at the inlet. This thread is still in use today as the standard inlet thread as corporation stops of all makes. For many years, this thread was referred to as the "Mueller Thread", and when it was adapted as the standard thread for all makes of corporation stops by the A.W.W.A., it became the "C.C." Thread. "C.C." stands for Corporation Cock. The word corporation was used because the cock, or stop as it is now referred to, is the property of the Corporation.

Other necessary tools required for the new machine, such as Combined Drills and Taps and screw plugs, were also developed.

Thus was launched the H. Mueller Manufacturing Company, which has grown from a little "Gun Shop" in 1857, to the latest edition of modern plants, such as the plant located in Milton Ontario, into which the Canadian operation has just recently moved.

This machine became the forerunner of numerous drilling and tapping machines for both waste and gas utilities.

There are machines in the market made by companies other than Mueller, but since the Mueller Company was the leader in making changes and improvements, the paper will refer only to Mueller machines.

In 1906, the original machine was modified into the "B" Tapping Machine for 3/4" and 1" connections and the "A" Machine, a larger version of the "B" machine was introduced for 1 1/4", 1 1/2" and 2" direct tappings into the mains. Further refinements to the "B" Machine were introduced in 1957 with the introduction of the B-100 Machine - so named to mark the 100th Anniversary of the company's existence.

Improvements included in the B-100 are the self-lubricating boring bar oil reservoir with "O" ring seals and wiper ring, a chrome-plated boring bar, a tool guide, automatic feed and power operator - which can be electric or air operated.

Also produced in the early days were the dry or open tapping machines such as the H.M. Machine and the "J" Tapping Machine. This "J" Machine is coming back to popularity, with contractors in particular, because they tap a lot of service connections before the mains are pressurized.

When service saddles came into being the Mueller #20 Machine, the forerunner of the E and D series machines, was developed.

The theory of drilling through a valve means, the same as in the original machine, was used except the valve means is the corporation stop which is screwed into the saddle, which is secured on the main.

Some of these machines were also used in the gas industry. The speaker can recall in the early days of the gas industry when low pressure manufactured gas was prevalent, in places such as Winnipeg. Asphyxiation was common because in those days, it was a common practice to drill and tap a hole in the main and the let the gas flow while an open stop with an I.P. thread nipple on

the inlet was screwed into that hole.

On a very dry day, that low pressure would not blow out of the trench and when breathed in by the operator, he would, all too often, be overcome by the gas fumes resulting sometimes, in death.

In 1950, the No Blo Line of equipment was introduced in the Gas Industry and this No Blo line again utilized the theory of drilling through a valve means to prevent the escape of the gas whether it be low pressure 2 P.S.I. or 1440 P.S.I.

The aforementioned #20 Machine evolved into the E and D series drilling machines, which were originally developed for the gas industry where they are capable of handling pressures with safety up to 500 P.S.I. These two machines and their successors E-5 and D-5 are popularly used in the Water Industry to drill through corporation stops and saddles into all types of mains for 1/2" through 2" service connections.

These two machines were modified to permit the use of power operators and automatic feed mechanisms.

The D-4 machine was introduced in this conference area in the late '50s to cut the costs of the previous methods of making 1 1/4", 1 1/2" and 2" connections which consisted of, in the 2" sizes, drilling and tapping the main and inserting four 1" corporation stops connected with 1" copper tube to a four branch brass connection with 1" inlets and a 2" outlet. In this case, the cost of the four 1" corporation stops, the four pieces of 1" tubing, the four branch connector and the making of nine copper flare joints, far exceeded the cost of one only 2" corporation stop, a saddle and the making of only one flare joint.

This method of making 2" connections became very popular because you only had to make about five 2" connections this way to save the cost of the drilling machine and from there on, they were saving money hand over foot.

Particularly in the Gas Industry, Machines were developed to keep pace with the increasing pressures used in the transmission and local distribution systems. It is not uncommon to have pressures up to 1440 P.S.I. in Transmission lines and the local Gas Co. distributes gas at 50 P.S.I. Most of the later drilling machines made for the gas industry have a maximum safe working pressure of 500 P.S.I. However, there are two machines, the DH-2, a power operated machine with automatic feed and the DH-5 which can be either hand or power operated, which are pressure balanced, that is these high pressures are balanced in the machine so that even against 1440 P.S.I. the boring bar can be advanced by hand.

These gas drilling machines are mentioned because the water industry has benefited from some of these machine innovations. For instance, the automatic feed machine on the E series and D series machines were first introduced in the gas industry.

Combined drills and taps are made of carbon steel for use on cast iron pipe whether it be ductile or just plain spun cast. These tools are made of high speed steel for use in steel mains. The letters H.S. are stamped on the shanks for identification.

With the introduction of Asbestos - cement pipe, in the late 40s, new tools had to be made of a special composition material which would resist the abrasive action of the cement in these pipes.

This tool can be readily identified by the letters "Cem-Res" stamped into the shank of the tool. The drill end is longer to accommodate the thicker wall of the A.C. pipe and the back side of each of the threaded sections of the tap is flattened to allow more space between the segments to accommodate the resultant cuttings.

These tools are required when tapping A.C. pipe, cement lined cast iron and hypercon pipe. In the not too distant future, there will be carbide tipped tools for use on multi-material pipes.

In the early 60s, it was necessary to produce new tools with which to top P.V.C. pipe. These tools have carbon-steel combined shanks and taps and shell cutters which are screwed onto the top portion. These shell cutters have a single cutting tooth. With a little practice coordinating the speed of the feed with the rotation of the boring bar, you should be able to retain the coupon inside the shell-cutter and have a very minimum of chips which may flow down the main, into service lines, and eventually foul up meters.

Series C-900 P.V.C. pipe can be tapped directly with these tools in the B-100 machine or through a corporation stop and service saddle with a lightweight PL-2 drilling machine in sizes up to 1" or in the case of 1 1/4", 1 1/2" and 2" sizes with the E-series or D-series machines.

To properly use these tools, Mueller recommends the following:

1. Make sure your machine is in good working condition - most tool breakage is caused by poorly maintained machines.

2. Select the proper machine tools depending on the pipe to be tapped.

3. When tapping cast-iron or steel pipe, Mueller recommends the use of its cutting grease, which is a non-toxic mixture with a lard base, liberally coating the drill end, flutes and cutting teeth. This grease will make the cutting easier and also pick up many chips which otherwise would fall into the main.

4. When tapping A.C. pipe, <u>do not use Mueller cutting grease</u> on the tool because this grease has a softening effect on the pipe. As well, it makes a mortar mix which binds up the tool operation.

5. If a "Cem-Res" tool has been used even once on A.C. pipe, do not use it to top any other type of pipe.

6. When tapping P.V.C. pipe, where again you use the cutting grease. The inside of the shell cutter should also be lubricated. This will help removal of the coupon. When the cut is completed in P.V.C. pipe, wipe off any excess cutting grease left on the outside of the pipe.

7. At the end of a tapping day, you should wipe down the machine, particularly the boring bar and the tools, with an oily rag to prevent corrosion. Clean the machine of chips and make sure that, in the case of the B and B-100 machines, the by-pass ports are not plugged.

It should also be noted that the B-100 machine is tapped and plugged, with a bronze plug, 1/2" I.P. hole in the bronze body and an I.P. male threaded inlet valve which has a garden hose threaded outlet. Remove the bronze plug, screw in the valve, hook up a garden hose to the outlet and run it out of the trench into the gutter. Through this set-up, and this is particularly recommended when tapping A.C. pipe, you can flush out the small chips and cuttings

as soon as the point of the tool penetrates the pipe. There has also been an evolution in the case of drilling machines used to make lateral connections to existing mains without interrupting the flow in the main.

The earliest Mueller Machine came into being about 1906 and was known as a "C" machine. It was an open design machine and was hand operated. Even this early machine was equipped with automatic feed. It was capable of making 2", 3", 4", 6", and 8" cuts into 4" and 48" pipe through a special gate valve for control.

Cutters for this machine and some of its early successors consisted of carbon steel shell cutters and a pilot drill onto which the coupon was threaded inside the shell cutter.

Later C.C. Drilling Machines capable of cuts up to 12" were of a closed body design and ball dents in the pilot drill to retain the coupon and the major change was the addition of power operators - either air motors or gasoline engines and mechanical flexible drives. These larger machines are fitted with feed indicators which will stop the advance of the cutter when the cut is completed. This will prevent cutting into the far side of the main and stop machine damage.

To the best of the speaker's knowledge, carbaloy tipped tools were introduced during the Second World War, but were not available to industry at large until the immediate post war period. It was a natural step to add carbaloy tips to many of the cutting tools because of the resulting efficiency in cost cutting.

A word of caution regarding the use of carbaloy tipped cutting tools. You should only use power drives and automatic feed machines when cutting metal with carbaloy tipped tools. The resulting damage, particularly to shell cutters, is costly to repair.

MISA

N. Borodczak
Assistant Director
Water Resources Branch
Ontario Ministry of the Environment

MISA is an acronym. It stands for Municipal-Industrial Strategy for Abatement and is a new program that was announced by the Minister of the Environment, the Honorable Jim Bradley in June of 1988 in a White Paper released to the public for review and comment. The goal of MISA is the virtual elimination of persistent toxic contaminants discharged through liquid effluents into Ontario receiving waters.

MISA is a regulatory program. It will control and reduce the amount of persistent toxic contaminants in all municipal and industrial effluent discharges. Normally, industries collect and segregate wastes, provide treatment and discharge a treated effluent to a natural receiver. MISA will look after these kinds of discharges. If we look further, we see that municipalities collect wastes from industries, commercial sources and residential areas, convey them to sewage treatment plants and also discharge treated effluents to natural receivers. MISA will look after municipal plant discharges as well. Both industries and municipalities will have air emissions and produce sludges. These emissions will be covered by other Ministry programs-Regulations 308 and 309 respectively which are presently under revision. Through MISA, these other areas will be looked at only to determine whether in providing effluent control facilities, the problems are transferred from liquid effluents to the sludge or to the air. Once such transfers are identified, then the other respective agencies will be informed to take whatever action is necessary.

The MISA initiative has two major components. The first component deals with regulation development and the second deals with water quality impacts.

Within the regulation component, the Ministry is proposing to promulgate two sets of regulations: the first deals with effluent monitoring and the second with effluent limits and compliance requirements. The monitoring regulation will require each discharger to analyze their effluents for toxic and conventional contaminants. The monitoring regulation will be in place for one year and will set out specific sampling, analytical, flow monitoring and data reporting protocols to ensure that all dischargers sample, analyze and report in the same manner. This will permit the Ministry to compare effluent results of industries within the sector, and also to make comparisons from sector to sector. Even though the monitoring regulation will require the dischargers to carry out a self-monitoring program, it is still the Ministry's intention to carry out an auditing program to ensure that the monitoring requirements are being complied with. The main purpose of the monitoring regulation is to establish a proper and verified database which can then be used as background to the development of the second series of regulations which are the limits regulations.

The limits regulations will specify allowable concentrations and loadings of toxic pollutants. The limits will be based on best available technology economically achievable (BATEA). Limits will be set for each industry within the sector and will likely set out requirements in terms of concentrations and loadings tied to production rates.

The compliance regulations will set out minimum requirements for a sector across the Province.

It is recognized, however, that in certain instances, because of restricted water usage or particular sensitivity in the receiver, it may be necessary to require the discharger to provide additional controls beyond those stated in the compliance regulations. In these instances, the MISA program will rely on its second major component and that is water quality impact assessment. Dischargers will be required to carry out a study of the receiver to determine whether their effluent discharge, even thought it meets the regulatory requirements, is still having adverse water quality impacts. These water quality impact assessments will be based on biological impact and will also take human health effects into consideration. They will be site-specific, rather than being applied across the sector, across Ontario, and will establish tighter limits based on concentration and loadings. At the present time, the Ministry is undertaking a number of pilot site studies to determine the impact of wastes on receivers, to develop impact modelling techniques. It is the Ministry's intention to apply the water quality track after the first round of compliance regulations have been promulgated and facilities installed.

The program's sequence as established under MISA is straightforward. Dischargers have been invited on a voluntary basis to carry out characterization and waste monitoring to obtain a preliminary assessment of the nature of their effluents. Information collected from the pre-regulation monitoring program, from historical information on file either with the Ministry or with other jurisdictions and knowledge of the processes used in the plant operations will be considered to develop the list of monitoring parameters and frequency of sampling to be placed into the monitoring regulation. The database collected from the monitoring regulation will be used to establish the compliance regulation which sets out the effluent limits and also describes the compliance responses. Water quality assessments are to be carried out to determine whether further controls are necessary beyond those that are stipulated in the compliance regulations and these controls will be implemented either through amendments to Certificates of Approval or through the issuance of specific Control Orders.

For administrative purposes, the industrial dischargers have been divided into nine (9) major industrial sectors: petroleum refining, organic chemicals, pulp & paper, metal mining and refining, iron and steel, industrial minerals, inorganic chemicals, electric power generation, and metal casting. The municipal sector also has been divided into two major categories: the first deals with the sewage treatment plants and the second with industries discharging their wastes into the sanitary sewer systems. Since municipalities would be subject to monitoring and compliance regulations under the MISA program, it became necessary for the Ministry to establish a program to assist municipalities in controlling industrial discharges to sanitary sewers. Towards that end, the Ministry of the Environment retained the services of consultants who reviewed how other jurisdictions (Europe, U.S. and Canada) handled such discharges and two reports were released summarizing their findings. Based on information obtained from these reports and the U.S. experience, the Ministry of the Environment released a discussion paper for public review and comment outlining a strategy that might be employed in Ontario to deal with industrial discharges to sanitary sewers. The public participation period will end towards the end of 1988.

As part of the regulation development process, a Joint Technical Committee has been established for each of the industrial sectors and for the two municipal sectors to provide a forum where industry and government develop both the monitoring and the compliance regulations. These committees take their representation from the industries, their association, the federal government, the Ministry of the Environment and also other provincial ministries that deal extensively with the sector in an effort to develop the regulations through a consensus process. Sub-committees are established under the Joint Technical Committees which are normally task-

Sub-committees are established under the Joint Technical Committees which are normally task-related and again, they take their representation from industry and government in order that the tasks might be completed as a joint effort. The tasks include regulation writing, establishing flow monitoring capabilities, developing sampling techniques, etc.

The MISA program has a very strong public component. Initially, the program was outlined in a White Paper released to the public for review and comment in June of 1986. Whenever a regulation is developed, it is made available to the public in draft form for review and comment prior to promulgation. All data collected from the monitoring regulation is also available to the public on request. Further, the Minister of the Environment established the MISA Advisory Committee which is made up of non-government experts representing industry, the academia and the environment pressure groups to review and advise the Minister on the regulations produced by the Joint Technical Committee. A member of the Advisory Committee also sits as an observer on the Joint Technical Committee to permit dialogue and exchange of information.

It is interesting to note that the MISA program has gained a great deal of national perspective. This has been obtained for the most part since there is Federal representation on the Joint Technical Committee. Representatives from Environment Canada have provided the Ministry of the Environment with a broader perspective and a national viewpoint, as well as technical assistance. They were also instrumental in setting up meetings with other Provinces whereby the MISA program could be presented to other provincial jurisdictions.

Before proceeding with the MISA program, the Ministry of the Environment developed its own Effluent Monitoring Priority Pollutant List (EMPPL), similar to the priority pollutant list of 126 parameters used in the United States. Ontario's EMPPL list contains approximately 180 parameters for which there are analytical protocols for only 135 parameters. The criteria used to establish such a list included environmental behaviour parameters such as environmental transport, persistence and bioaccumulativity and toxicity parameters such as acute lethality, sub-lethal effects on animal and plant life, teratogenicity, genotoxicity, mutagenicity and carcinogenicity. This list of compounds is used as a primary reference opposite which the sector's monitoring lists are established.

In 1987, the Ministry of the Environment established the MISA Office and set up the administrative processes used to develop all the necessary regulations. All the Joint Technical Committees have been struck and are presently involved in developing both the sampling and compliance regulations. During the discussions at each of the Joint Technical Committees, it appeared that there were a number of common issues that were continuously brought forward by each of the sectors. The Ministry of the Environment has therefore taken these common aspects and produced a general regulation which outlines the protocols for sampling, analysis and flow measurements and also sets out definitions that are common to the sectors. Simply put, the general regulation outlines the "how to" which leaves the specific sector regulations for each industrial sector to indicate what is to be done and under what circumstances. In order to ensure that differences between the sectors can be considered, a statement has been made in the general regulation which allows the specific sector regulation to overrule some of its requirements. This regulation was promulgated in June of 1988 and released to the public in July of the same year.

The monitoring regulation for the petroleum refinery has been promulgated in June of 1988 and publicly released in July. The industry has been given time within which to obtain the necessary sampling and flow measuring devices and monitoring equipment in order that monitoring can commence in December of this year. The monitoring regulation will last for approximately

their effluents. The industry is required to monitor for approximately 149 parameters on a monthly basis, approximately 17 parameters on a weekly basis (three times per week) and 3 parameters on a daily basis. The industry will also be required to carry out two characterizations opposite the entire EMPPL list twice during the life of the regulation and then every three years or after process changes have been implemented which impact on the quality of the effluents discharged to the natural receiver.

The organic chemical sector has approximately 19 plants. The industry has completed its pre-regulation monitoring program and in fact, the regulation has been released to the public for review in draft form. It is expected that the regulation will be promulgated later this year or in early 1989.

The mineral resource industry has been divided into two major categories. The first dealing with metal mining and refining, and the second with industrial minerals. Two Joint Technical Committees have been established for each of these groups and these are presently underway in order that monitoring regulations might be negotiated for both groups. The mining and refining group contains approximately 50 active sites and deals with approximately 100 abandoned sites. This group deals with such mining operations as gold, silver, nickel, copper, etc. The industrial minerals group has approximately 2,000 facilities which include sand and gravel operations, limestone operations, gypsum operations, etc. It is expected that the draft monitoring regulation for the mining and metals finishing sector will be released to the public this fall to be followed by a monitoring regulation for the mineral sector early next year.

There are approximately 27 pulp & paper mills operating in the Province of Ontario which will be coming under the MISA program. In completing their pre-regulation monitoring program, it is unfortunate that the industry chose to combine all their effluent samples proportional to flow into one sample bottle per industry in order to assess the nature of materials released to the environment. Because of possible masking and dilution, some of the data provided to the Ministry is of a suspect nature. Negotiations have been proceeding to the extent that the draft monitoring regulation is expected to be released to the public towards the end of 1988.

Since toxicity from kraft mills will be an important issue to be resolved under MISA, the Ministry of the Environment undertook to establish an Expert Committee on Kraft Mill Toxicity by retaining the services of three non-government experts in this field. Dr. John Sprague, an expert on toxicity from the University of Guelph; Mr. Neil McCubbin, the Consulting Engineer familiar with the pulp & paper process operations; and Prof. Norman Bonsor, Head of Economics at Lakehead University, were chosen to review the Kraft Mills operation in Ontario with a view of identifying the toxic components and determine the technologies that might be implemented to help reduce toxicity in the kraft mill effluents. Mr. Bonsor was also asked to participate on this committee to assess the economic impact on the industry of each of the control measures implemented. The Expert Committee report has been completed and released to the public in April of 1988.

There are seven iron and steel operations in the Province of Ontario. The industry has completed its pre-regulation monitoring program and the regulation writing team under the Joint Technical Committee has finalized its draft monitoring regulation. It is expected that this regulation will be available to the public for review and comment in November of 1988.

The electric power generation sector includes six thermal generating stations, three nuclear generating stations and 68 hydro electric power plants. For the most part, these are the operations that are presently being run by Ontario Hydro. The industry has completed its pre-

regulation monitoring program and a regulation team has been established to write the monitoring regulation. At the same time, discussions are underway with the AECB in order to avoid jurisdictional difficulties.

The inorganic chemical sector has 21 facilities. Pre-regulation monitoring is virtually completed and it is expected that the monitoring regulation will be available to the public for review and comment in mid-1989.

The last industrial sector is the metal casting sector which contains approximately 50 plants. This is a sector that was produced when iron and steel operations were reviewed. It was found that the foundry operations could not be combined with basic steel manufacturing and therefore, it was necessary to create this new metal casting sector. The pre-regulation monitoring program is underway and it is expected that the monitoring regulation will be available to the public in late 1989.

The other major sector is the municipal sector which deals with 407 sewage treatment plants constructed across the Province of Ontario. Two Joint Technical Committees have been established; one to deal with the sewage treatment plants themselves and the other to deal with the implementation of the program dealing with the control of industrial discharges to sanitary sewers. The monitoring regulation for the sewage treatment plants is expected to be completed in 1989. The Discussion Paper on Sewer Use Control has been released to the public for review and comment. The program will be finalized depending upon the natural and the extent of comments received by early next year.

As can be seen, MISA is an ambitious program undertaken by the Ministry of the Environment. Through the monitoring regulations, the Ministry of the Environment will be able to establish a verified database on the quality of effluents discharged from industries and from municipal plants. This kind of information will be valuable in establishing the compliance regulations that are to follow. The program also recognizes the actual receivers and that some requires special considerations when installing control facilities. Since the compliance regulations will be based on best available technology economically achievable, it means that the Ministry is aware of the economic difficulties that may be imposed on industry in providing pollution control and is intending to consider such difficulties in developing regulations.

Removal of Fish Pathogens from Inter-Basin Transfer Water

Charles D. Turner
Associate Professor of Civil Engineering
University of North Dakota
Grand Forks, North Dakota 58202

Introduction

The potential transfer of biota from the Missouri River Basin into the Hudson Bay Basin has become the central argument for not diverting water via the Garrison Diversion Project into either the Sheyenne River drainage or the Devils Lake Basin. Both the Sheyenne River and Devils Lake drain into the Red River of the North which is part of the Hudson Bay Basin. Fish species of concern are the Rainbow smelt, Utah chub, Shortnose gar and Gizzard Shad. Fish pathogens are IHN, Yersinia ruckeri and Polypodium hydriforme. Aquatic plants also pose a potential problem.

This paper combines a historical perspective of the Garrison Diversion Unit (GDU) with a review of earlier efforts to design an effective barrier to biota transfer and current research on direct filtration. Design goals have changed over time as issues have been clarified in an open arena of political, social and technical input. Research efforts, reviewed in this paper, focus on direct filtration technology that would produce biota free water for diversion into the Hudson Bay Basin.

Historical Perspective of Garrison Diversion Unit

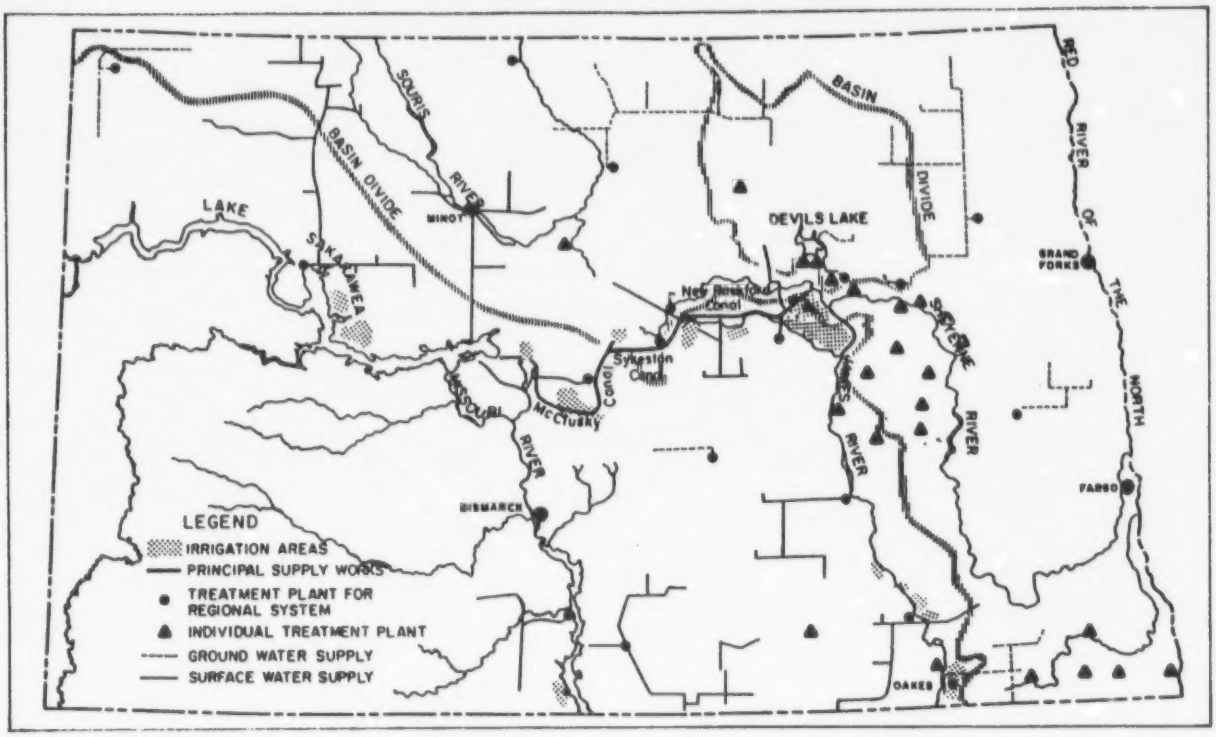
The Garrison Project was authorized by the Flood Control Act of 1944 as part of the Pick-Sloan Plan. The Garrison Diversion Unit (GDU) portion of the plan was originally proposed primarily as a project to irrigate 1,007,000 acres of land both within and outside the Missouri River Basin. In 1965 the project was reauthorized with 250,000 irrigated acres[1]. Construction of project facilities was slow and opposition to the project had grown over the years. In 1984 the Garrison Diversion Unit Commission was created by Public Law 98-360. The law creating the Commission was the work of Senator Mark Andrews, R-N.D. Senator Andrews wanted to see the project move ahead.

The "Final Report" of the Garrison Diversion Unit Commission was published on December 20, 1984 recommending 130,940 irrigated acres as shown in Figure 1. The report placed a strong emphasis on municipal and industrial water supply[2]. In May of 1986 the United States Congress enacted the Garrison Diversion Reformulation Act of 1986 to implement the Commission recommendations with a number of specific exemptions and changes. Changes that effect the diversion of water into the Hudson Bay Basin are as follows[3]:

1. A Sheyenne River water supply feature and water treatment plant is to be constructed that is capable of delivering 100 ft^3/s of treated water to the Sheyenne River Basin for the cities of Grand Forks, Fargo and surrounding communities.

FIGURE 1

Garrison Diversion Commission - 131,000 irrigation acres
with emphasis on municipal and industrial water supply



2. Lonetree Dam and Reservoir remain as authorized features of the project, but cannot be constructed until: a) the Secretary of the Interior has determined there is a need for the dam by methods employed for water resource feasibility studies submitted to Congress, b) consultations with the Government of Canada have reached a conclusion satisfactory to the Secretary of State and that no violation of the Boundary Water Treaty of 1909 would result, and c) Congress has been informed.

The Lonetree Dam site is located on the boundaries of the Sheyenne River, James River, and Devils Lake basins. The reservoir is considered necessary for regulation of irrigation water that would be delivered into Hudson Bay Basin drainages. Construction of the Lonetree Dam is viewed as central to delivery of water outside the Missouri River Basin by project supporters.

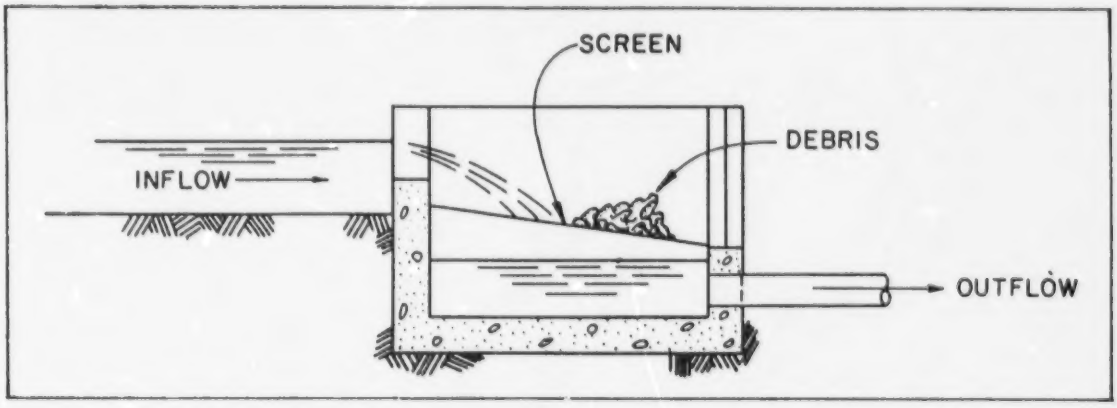
Biota Transfer History

In 1969, the Government of Canada expressed its concern that the Garrison Diversion Unit would violate the 1909 Boundary Waters Treaty. Article IV of the treaty states that "waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other." Concern over treaty obligations provided the impetus for the design and construction of biota barriers.

Early biota barriers centered around the use of mesh screens through which all interbasin transfer water would be filtered. Figure 2 is a general diagram showing fixed mesh screen operation. A 1975 design made use of number 40 mesh screens (0.432 mm opening) supported by a 2-mesh screen. The facility was under constructed on the McClusky Canal approximately eight miles north of the Town of McClusky and was partially complete when construction was stopped in 1977. The structure was built but screens, trashracks, debris-handling and other equipment had not been installed.

FIGURE 2

Schematic of Fixed Fish Screen Operation



In 1975, Canada and the United States referred to the International Joint Commission (IJC) the matter of potential pollution of boundary water by the GDU. One request was that the impact on commercial and recreational fisheries in Manitoba be investigated for possible introduction by the GDU of foreign fish species, fish diseases, and fish parasites. The resulting 1977 IJC report concluded as follows:

> "That because the 'closed system' and the McClusky Canal Fish screen cannot with any certainty prevent biota and disease transfers which would cause sever irreversible damage to the ecosystem and, in particular, to the commercial and sport fisheries in Canada, those portions of the Garrison Diversion Unit which would effect water flowing into Canada not be built at this time."

Construction on the McClusky fish screen was halted and the Bureau of Reclamation set up a Fish Screen Task Force in December 1977 to review the McClusky Canal Fish Screen. The Task Force concluded that operational techniques, sand filters, traveling screens, poisons, violent hydraulic action, electrocution were not as feasible as a stationary screening system.

Based on these conclusions, the Brekken-Holmes field test facility was constructed in 1979 and operated for three years[4]. As a result of these tests, the "McClusky Canal Fish Screen Development and Verification" report was released in 1982. This report recommended the use of

dual 70 mesh screens (0.198 mm opening). The screens were tested at an average filtration rate of 52 mm/s (75 gpm/sq ft). The screens would be preceded by a trash rack, radial gates for flow regulation, and traveling screens. Reject water containing debris would be transferred to vibrating screens and the screened trash disposed of in a lagoon. These screens were proposed to remove fish, fish eggs, and larvae of fish species found in the upper Missouri River.

The inherent problem with screens is that the 0.198 mm openings are too large to remove bacterial fish pathogens that can have diameters less than 0.001 mm.

Direct Filtration

Direct filtration is a relatively new technology that is being used to treat municipal water supplies in locations such as Toronto[5], Ontario; Las Vegas, Nevada; Springfield, Mass.; and Prospect, Australia[6,7,8,9]. Direct filtration eliminates the gravity settling operation from the coagulation, flocculation, gravity settling, and filtration chain of operations. The process also produces less sludge and, in some instances, has been successfully applied with the flocculation operation also deleted. Direct filtration can significantly reduce capital, operation and maintenance costs while providing a safe, potable water.

The application of direct filtration is limited by the amount of turbidity in the raw water supply. Waters with high suspended solids concentrations are not considered suitable because of the large quantities of sludge that would have to be removed by the filter. High sludge quantities lead to short filter runs and a large percentage of the filter water must be used for backwashing. This destroys the economics of the process. Culp states that wash water requirements should be 6 percent or less of the total water production[10].

The effect of suspended solids is evidenced by the shortened filter runs encountered when algal concentrations exceeded 1 000 asu/mL[123]. Research by McCormick and King, however, achieved eight hours of filtration with less than 2.4 m (8 ft) of head loss for an algal concentration of 28 000 asu/mL[11]. Run time and head loss are dependent on coagulant type and dosage, polymer usage, and the filter media material, size and depth.
Since direct filtration depends on storage of the floc in the interstitial pore space, multi-media and mixed media filters are used to provide the greatest usable storage volume. Dual media filters of coal and silica sand are the most common. Since flocculation can occur within the coal layer, the depth becomes important for adequate flocculation as well as floc storage. McCormick concluded, based on work at three different locations in Virginia, that a filter media configuration of 51 cm of 1.3-mm e.s. coal and 25 cm of 0.45 mm e.s. silica sand was the most effective tested when all variables were considered.

A second problem area for direct filtration is low water temperature. Low water temperatures can lead to problems with afterfloc formation. Floc forms and grows slowly at low temperatures (1-5°C), particularly if the water has a low hardness concentration. The flocculation operation is necessary, under these conditions, to allow the floc adequate time to grow.

Las Vegas attempted to operate a full-scale direct filtration facility without flocculation. Monscvitz[3] reported that the Las Vegas facility had to add on flocculation to the process after experiencing operational problems.

Hydraulic loading rates of 3.5 mm/s (5 gpm/sq ft) are common and rates of 7.0 mm/s (10 gpm/sq ft) have been demonstrated. High filtration rates are generally associated with shorter filter runs and a lower total volume of water filtered prior to backwash. Shorter filter runs cause

the percent of backwash water to increase relative to total filtered water production.

The removal of coliform bacteria, an indicator organism for the possible presence of human pathogens, is directly related to turbidity reduction. When turbidities in filtered water were reduced to 0.10 ntu or less, coliform bacteria removal was practically 100 percent[5]. Current public water supply standards in the United States require filtered water to have a turbidity of 1.0 ntu or less. Turbidity in this range enables disinfectants such as chlorine or ozone to be completely effective in the removal of human pathogens.

Fish Pathogens and Direct Filtration

Direct filtration systems are being operated in major municipalities and have proven effective in the reduction of turbidity and human pathogens. The removal of fish pathogens has, however, not been documented. Prior to acceptance of direct filtration for biota removal, the actual removal of fish pathogens must be proven.

Other methods of filtration are ultra filtration, slow sand filtration, and high rate filtration through granular media without chemical addition. Ultra filtration can remove bacterial size organisms but it has high capital and operation costs. Slow sand filtration is not practical for filtering large volumes of water in northern climates. The low filtration rates make very large filter surface areas necessary and the cost of structrues becomes prohibitive.

Granular media filtration without chemical coagulation will not remove high percentages of bacterial pathogens. Straining is an effective mechanism when the ratio of the particle size to the medium grain size is greater than 0.2[12]. If effective size is used as the medium grain size, a 0.45mm e.s. sand will remove 0.09 mm particles. Bacteria are often smaller than 0.001 mm. Therefore, granular filtration must make use of a chemical coagulant to ensure enmeshment of bacteria in the floc.

Based on this brief review of filtration processes, direct filtration emerges as the most cost effective method of filtration that could prove effective in removing fish pathogens.

Research on Direct Filtration

The University of North Dakota Energy and Mineral Research Center and the Civil Engineering Department has been awarded a research contract through the North Dakota Water Resources Research Institute to investigate direct filtration for biota removal. The objective of the research is the evaluation of the direct filtration process for fish pathogen removal using a dual media bench scale model operated on Garrison Diversion water and seeded with a fish pathogen such as Yersinia ruckari or a surrogate.

The research involves the construction and operation of a high rate direct filtration bench scale laboratory model. Support operations include the selection and culturing of selected fish pathogens for seeding the raw water, evaluation of fish pathogen surrogates and collection of water from the Garrison Diversion project so that the background conditions are as close as possible to those actually encountered in the field. Appropriate procedures for pathogen identification and seeding are being selected and developed by John Gallegher, a research microbiologist at the University of North Dakota Energy and Mineral Research Center. Disinfection of the filtered water is not being undertaken in this research.

The general bench scale testing procedure will be as follows:

1. Selection of the optimum coagulants and polymers using standard jar testing procedures.

2. Continuous coagulation of the raw water during each filter run.

3. Continuous feeding of the coagulated and flocculated water to the dual media (anthracite and sand) filter.

4. Monitoring of head loss during the filter run.

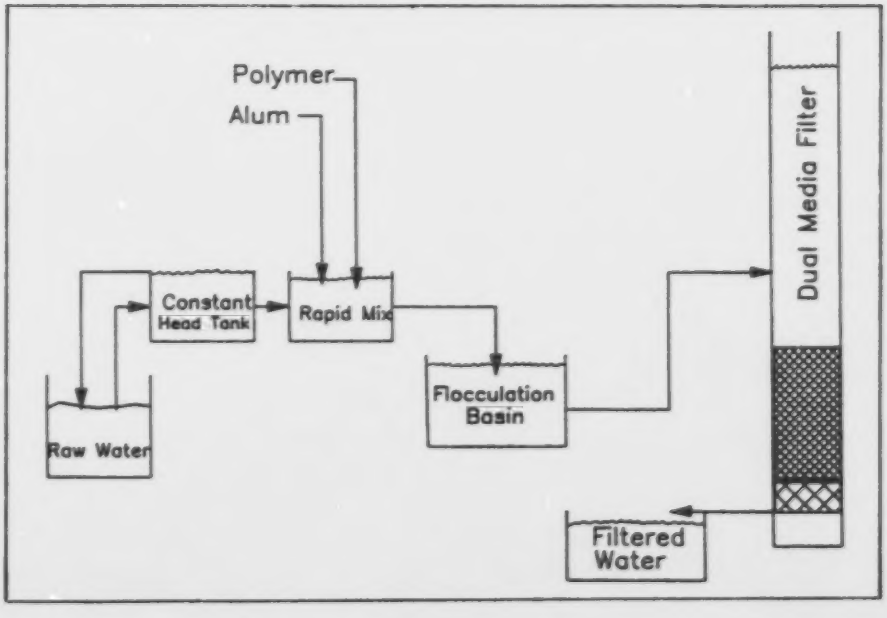
5. Sampling of the influent and effluent for test parameters such as turbidity, pH, temperature, algal counts, and seeded fish pathogen numbers.

A schematic of the bench scale filtration model is shown in Figure 3. The filter will be a dual media filter using 50 cm of 1.3 mm e.s. coal and 25 cm of 0.45 e.s. silica sand. The filter column will be constructed of acrylic tubing. Column dimensions will be 350 cm high and 9 cm in diameter.

Water collected from the Garrison Diversion project will be seeded with Yersinia ruckeri or a surrogate prior to coagulation. The selection of the appropriate fish pathogen is being based on the ability to obtain and culture the fish pathogen in adequate numbers for testing and pathogen characteristics such as viability and relative threat to the Hudson Bay drainage. The bench scale tests will be conducted over a range of filtration rates, algal concentrations, and water temperatures that are representative of operating conditions that would be encountered in a prototype system.

FIGURE 3

Schematic of bench-scale direct filtration model



Expected Results

Results from this research will assist in the evaluation of direct filtration as an appropriate technology for the removal of fish pathogens from Garrison Diversion Unit water for transport into the Hudson Bay Basin. Many waters are not suitable for direct filtration. This research will provide valuable results on the suitability of GDU water for application of direct filtration technology and its effectiveness.

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COATINGS FOR WATER AND WASTEWATER TREATMENT PLANTS
PAST, PRESENT AND FUTURE

Daniel H. Golfer
Engineering Services Manager
Ameron Protective Coatings Division

The science of coatings selection for protection of water and wastewater treatment facilities has benefited over a span of several decades from the advancement in coatings formulation technology. Corrosion engineers responsible for maintenance of these facilities originally had only oil based and asphaltic-based products to rely on, that exhibited limited service life and required frequent maintenance to keep plants in service.

The key performance characteristics required for long-term performance in these facilities may be enumerated as follows:

1. Non-biodegradability - essentially complete resistance to any physical or chemical deterioration caused by bacterial action or by other biological processes within the facility.

2. Immersion resistance - for protection of submerged steel, concrete or other material of construction, very long term service capability is required in continuously wet, warm, moving water contact.

3. Chemical resistance - successful coatings must withstand continuous exposure to acid, alkaline and chemical contact.

4. Abrasion resistance - resistance to wear is needed from the abrasive action of moving suspended solids.

5. Resistance to weathering - those coatings used on exterior, non-submerged surfaces must display retention of colour, gloss, and protective properties in a combination of sunlight/ultraviolet exposure, daily and seasonal temperature fluctuations, rain, snow, high humidity, chemical fumes, and moisture condensation. They must be available in a wide colour array to meet specific municipal colour standards.

Clearly, no one coating possesses all these requisite properties, and typical practice is to choose different generic coatings types after sorting the service requirements into classes:

- Immersion
- Non-Immersion - Interior
- Non-Immersion - Exterior
- Normal or Corrosive Atmospheric Service
- Abrasives
- Concrete Substrate
- Metallic Substrate

PRINCIPAL COATING TYPE

Coal Tar-Epoxy

Coal tar-epoxy coatings have found very wide use in submerged areas of waste treatment plants, and have amassed an excellent track record for long term service. As a class, they display water and chemical immersion resistance, abrasion resistance, non-biodegradability (see below), and resistance to fluctuating temperatures.

It is important to note that formulation with an appropriate curing agent for the coal tar-epoxy blend is a must to ensure non-biodegradability. Some otherwise satisfactory curing agents (hardeners) for epoxies and coal-tar epoxies degrade rapidly under bacterial and biological attack; others retain original properties. It is known, for example, that coal tar-epoxies cured with amine-type curing agents are very satisfactory for sewage conditions. It is mandatory that the municipal agency or consulting engineer receive proper assurance, in the form of test or service data, that a proposed coal tar-epoxy coating will indeed perform properly in the intended environment.

An increasingly negative aspect associated with coal-tar epoxies is the strongly suspected cancer-causing (carcinogenic) property of the coal-tar pitch component, that if proven, can cause personal injury to application personnel. Evidence of this concern is the exclusion of use as a potable water tank and pipe lining by many regulatory jurisdictions, where coal tar-epoxy was formerly widely used.

Vinyl Coatings

Vinyls, or more properly, polyvinyl chloride copolymer-based coatings, have seen wide use in water and wastewater treatment facilities. Specific coatings are qualified as potable water tank linings. They show long term service in both interior and exterior non-submerged areas of waste treatment plants. Vinyls are characterized by excellent chemical atmospheric resistance, fume and humidity resistance, and general durability in severe weather exposure. Availability in a wide colour range is a plus feature.

These coatings are available in thin film versions requiring three or four coat applications, as well as "high build: versions needing only one coat over a primed surface.

CHLORINATED RUBBER COATINGS

These coatings, formulated from chlorinated rubber resin, resemble vinyls in many respects, possessing fume, humidity, moisture and weathering resistance. They have been fairly widely used in water/wastewater treatment plants. Like vinyls, chlorinated rubber coatings are available in both thin-film and high build versions, and are available in a wide colour range.

Toxicity concerns about chlorinated rubber have recently arisen, due to the approximate 8% residual content of carbon tetrachloride, an acknowledged carcinogen, in the CR resin as supplied to the coatings manufacturer. He, in turn, cannot remove this contaminant, and it is contained in the coating supplied to the coating contractor (with, of course, an appropriate mandated warning in the form of a Material Safety Data Sheet).

Chlorinated rubber resin manufacturers are strenuously working to remove carbon tetrachloride residuals from their products. Until this is achieved, extreme care in the application of these

coatings cannot be over-emphasized. If complete removal cannot be achieved, then it is only a matter of time when the legal personal injury liability ramifications will drive these products from the marketplace.

ALKYD ENAMELS AND LATEXES

These traditional architectural type coatings are used on non-submerged areas (indoors and outdoors), judged to be non-corrosive, where an appearance and aesthetic considerations are significant.

For exterior service, silicone modified alkyd enamels are used as upgrades of the standard alkyds. The inclusion of 20% to 30% by weight silicone content, based on resin solids, enhances colour and gloss retention of these products in severe weathering service. The increased cost of these paints is considered justified by some agencies due to improved appearance for longer time periods.

TYPICAL SPECIFICATION - VINTAGE 1970's

A typical consulting engineer's wastewater treatment plant specification in displayed in Table I. It relies heavily on the coal tar epoxy, vinyl chloride and alkyds described above.

SPECIFICATION UPDATE

For water treatment/storage service, where linings will be in contact with potable water, epoxy linings will be specified currently to replace the coal tar epoxy and coal tar enamel linings shown in Table I, Systems 11 and 12.

TABLE I

Wastewater Treatment Plant Specification

System No.	Service Condition	Coating System
1	Ungalvanized ferrous metal, general (indoors and outdoors, not buried or submerged) — normal atmospheric	1st: Alkyd primer 2nd: Alkyd enamel 3rd: Alkyd enamel
2	Galvanized ferrous metal, general (indoors and outdoors, not buried or submerged) — normal atmospheric	1st: Wash coat primer 2nd: Alkyd primer 3rd: Alkyd enamel 4th: Alkyd enamel
3	Ungalvanized ferrous metal, general (indoors and outdoors, not buried or submerged) — corrosive atmospheric	1st: Vinyl alkyd primer 2nd: High build vinyl 3rd: High build vinyl
4	Galvanized ferrous metal, general (indoors and outdoors, not buried or submerged) — corrosive atmospheric	1st: Wash coat primer 2nd: Vinyl primer 3rd: High build vinyl 4th: High build vinyl

TABLE I, cont'd.
Wastewater Treatment Plant Specification

System No.	Service Condition	Coating System
5.	Ferrous metal - submerged in water	1st: Amine-cured coal tar epoxy 2nd: Amine-cured coal tar epoxy
6.	Ferrous metal - submerged in wastewater or sewage	1st: Amine-cured coal tar epoxy 2nd: Amine-cured coal tar epoxy
7.	Ferrous metal - high temperature to 1000°F. stack and piping	1st: Silicone aluminum 2nd: Silicone aluminum
8.	Buried galvanized and black steel pipe	20 mil adhesive PVC tape wrap 2 plies
9.	Buried miscellaneous ferrous surfaces (valves and flanged joints)	Portland cement morter - 1/8" enclosed in 8-mil polyethylene sheet
10.	Steel water reservoir (exterior including accessories and appurtenant piping)	1st: Alkyd primer 2nd: Alkyd enamel 3rd: Alkyd enamel
11.	Steel water reservoir (interior excluding bottom and lower 8 ft of shell)	1st: Amine-cured coal tar epoxy 2nd: Amine-cured coal tar epoxy
12.	Steel water reservoir (interior bottom and lower 8 ft of shell)	1st: Coal tar primer 2nd: Coal tar enamel - 3/32 inch thick
13.	Non-ferrous metal, plastic and fiberglass (normal atmospheric indoors and outdoors, not buried or submerged)	1st: Alkyd primer 2nd: Alkyd enamel 3rd: Alkyd enamel
14.	Non-ferrous metal, plastic and fiberglass (corrosive atmospheric, indoors and outdoors, not buried or submerged)	1st: Vinyl primer 2nd: High build vinyl 3rd: High build vinyl
15.	Concrete and concrete block, indoors and outdoors, not buried or submerged	1st: Acrylic latex block filler 2nd: Acrylic latex finish coat
16.	Concrete, submerged in wastewater or sewage	1st: Epoxy primer/void filler 2nd: Amine-cured coal tar epoxy 3rd: Amine-cured coal tar epoxy
17.	Concrete slab subject to corrosive spillage	1st: Epoxy primer 2nd: Epoxy floor surfacing-1/8-3/16 in
18.	Concrete block and brick masonry (waterproofing, exterior, above grade)	1st: Masonry waterproofing 2nd: Masonry waterproofing

Further, where 2-coat coal tar epoxy systems are shown, these nowadays are replaced with a 1-coat high build coal tar epoxy coating/lining. Use of the 1-coat product eliminates the risk of intercoat delamination to which the older 2-coat products are prone, as well as reducing application labour costs.

Intercoat delamination in coal tar epoxies arises as a result of exposure of the first coat to ultraviolet sunlight for short periods of time, aging or exposure to moisture condensation (dew, rainfall, etc.). The result is a dismaying clean splitting of the second coat off the first coat, evidenced at any time after the second coat cures hard. There is no field inspection of the first coat that can be made to determine whether or not the second coat will bond to it. Passage of time after applying the second coat will not improve the situation. The second coat does not auto-delaminate, but is easily dislodged by impact, or scraping damage, or when submerged in water or sewage containing abrasive solids.

POLYESTER/VINYL ESTER LININGS

These specialty sprayable linings are 100% solids liquid compositions, developing thick (40 mil), tough, water and abrasion resistant films. They are not affected by bacterial action.

Typical specified uses are in submerged service on

- inside concrete walls of primary clarifiers
- trickling filters
- grit unit wet wells
- scum box interiors
- effluent boxes
- weir troughs
- slum and chemical storage

These products are an alternative to the coal tar epoxy shown in the typical specification, and are capable of long life service with a minimum of maintenance.

NEW COATINGS - WATERBORNE EPOXIES

A new class of epoxy coatings is beginning to be specified for non-immersion areas, including ferrous metal, galvanizing, existing coated areas, concrete block masonry, gypsum plaster and gypsum wallboard, and exposed concrete placed and precast substrates.

Waterborne epoxies will replace alkyds, vinyls, and chlorinated rubber coatings; they offer installation in fewer coats, and an applied coating this is more resistant to damage and more amenable to cleaning procedures, as well as the avoidance of hazardous and explosive fumes during application. They show the same order of resistance to moisture and corrosive atmospheric conditions as traditional solvent-based epoxies, but are not recommended for immersion service.

NEW COATING - SURFACE TOLERANT EPOXIES

This class of high solids, high build epoxy shows excellent compatibility over surfaces from which loose rust, loose paint, dirt, oil and grease have been removed, and will adhere to tight residues of rust, intact old coating, concrete and galvanized surfaces. Slight residual dampness prior to coating does not interfere with adhesion.

Consequently, these coatings are virtually ideally suited for maintenance painting where abrasive blasting is not permitted or possible, and fit a valuable niche in upkeep of water/wastewater facilities.

This class of product is used in non-immersion service in both normal and corrosive atmospheric environments.

POLYURETHANE COATINGS

Polyurethanes display unusual retention of appearance, colour and gloss on exterior exposure, together with hardness, abrasion resistance and excellent resistance to corrosive atmospheric service. They are not used for immersion service. They are offered in a wide range of gloss levels, including very high gloss not readily attainable from alternative coatings.

Based on this combination of properties, they have been accepted by some agencies and consulting engineers where special aesthetic and functional requirements coexist.

Newer versions of polyurethanes are both high build and self-priming thus lending themselves to broadened use at reduced installed cost.

COGENERATION FACILITIES

Inclusion of cogeneration capability into the design of waste treatment plants has expanded the requirements for corrosion control and selection of materials. The cogeneration power unit portion of the plant can be adequately protected with epoxy or epoxy/polyurethane systems. Low pressure digester gas (manufactured methane for cogeneration fuel) is corrosive and is effectively conveyed through fiberglass reinforced plastic piping to fuel storage tanks forming part of the cogeneration system.

THE VIEW AHEAD

We can confidently expect that, as coatings and materials technology continue to advance and improve, corrosion control of water and wastewater facilities will be increasingly effective and increasingly cost effective.

Significant areas of current active product development include:

- Solventless sprayable coatings that will eliminate film weaknesses caused by solvent evaporation.
- Surface tolerant coatings for submerged service.
- One-coat coatings to replace traditional 3-coat systems.
- Elimination of potentially toxic raw materials, without performance penalty
- Broadening the application temperature and humidity ranges, particularly at low temperatures and high humidities.

These an other advances will help assure even higher levels of asset protection in water and wastewater facilities.

COMMUNITY EMERGENCY PLANNING

Mark Bennett
Supervisor
Planning & Research
Manitoba Emergency Measures Organization

Introduction

Emergencies or disasters can happen anywhere at any time. In recent years the effectiveness of municipal emergency responses in Gander, Newfoundland and Hinton, Alberta, emphasized the importance of up-to-date municipal emergency plans. Both communities are quite small and fairly isolated, circumstances which are not unusual in Manitoba. Both communities experienced horrific transportation accidents. In Gander's case it was a plane crash, while in Hinton it was a train wreck.

Both communities had emergency plans in place. In the case of Gander, the plan had been tested with a simulated emergency exercise just prior to the actual emergency. Gander and Hinton have received much deserved credit for their response to very serious emergencies and for the effectiveness of their emergency plans. This is no surprise to those of us who support and practice emergency preparedness.

Both incidents have dramatically demonstrated that "it can happen here", and that the "here" can be any community, anywhere and at any time. If an emergency of this magnitude were to occur in a community without a plan, the resultant loss of precious time to establish an ad hoc plan would surely add to the suffering and magnitude of the emergency.

A provision of the new Emergency Measures Act of Manitoba, passed in 1987, stipulates that it is compulsory for municipalities to prepare an emergency plan. This paper provides a brief overview of the subject of community emergency planning. It will look at exactly what is an emergency? The escalating nature of emergency response will be discussed along with a cursory review of risk assessment. Subsequent sections will look at the plan and its development; the Emergency Operations Centre; and exercising the plan.

There are many elements to emergency preparedness, not all of which are covered in this paper. The focus is directed towards community emergency planning. Individual communities are frequently the first line of attack in combating emergencies or disasters, therefore, preparedness at this level is a very logical place to being to look at the broad topic of preparedness.

Definition of Emergency

One of the fundamental considerations in planning for emergencies is defining an "emergency". There are numerous and varied definitions of this term. For example, the Honourable Perrin Beatty, federal minister responsible for emergency preparedness, commented on this fact in a recent speech. A new federal Emergencies Act has been passed by the government to replace the now repealed War Measures Act. In referring to the new Act, Mr. Beatty noted that over 400 different words are either used in the Act or called up by reference to other statutes, in order to define the various kinds of situations envisaged by the term "emergency".

The Oxford Dictionary defines "emergency" as "A juncture that arises or turns-up; especially a state of things unexpectedly arising, and urgently demanding immediate action."

In Manitoba we have developed a more focused definition. It appears in the Emergency Measures Act and in both the Provincial emergency plan and municipal plan. Narrowing the definition for our purposes permits the development of plans which can remain necessarily concise. The broadest possible definition would require plans that filled volumes.

In Manitoba the Emergency Measures Act defines emergency as, "a present or imminent situation or condition that requires prompt action to prevent or limit

a) loss of life; or
b) harm or damage to the safety, health or welfare of people; or
c) damage to property or the environment".

There are four characteristics or criteria of an emergency which help to make it fit this definition.

1) It must be an abnormal situation.
2) There must be a clear potential for damage.
3) There is a requirement for quick response.
4) The response measures must be beyond those normally employed.

All four elements must be present to constitute an emergency, and therefore lead to a coordinated community or provincial response.

Emergency Response

In the first instance the responsibility for responding to emergencies rests with those most immediately affected. Experience has repeatedly shown that emergency response begins with the individual, escalates to the community and will involve higher levels of government in search of a resolution. Certain emergencies will be handled and mitigated by the individual municipal response. Those slightly more severe may require mutual aid arrangements with neighboring communities to facilitate an appropriate response. Some, which are larger yet, may require provincial involvement and assistance. Finally, in rare instances of truly catastrophic proportions federal government or even international aid may be required.

Risk Assessment

It is impractical, if not impossible, to plan for every contingency. It is, however, possible to assess the risks that a community faces. Assessing a risk involves consideration of two key factors. First of all, consider the frequency of occurrence, and secondly, the severity of the consequences of an occurrence should it happen. Various risks can be generically categorized into two groupings.

Natural Risks

- Severe weather
  - tornadoes
  - snow storms
- Flooding
- Forest Fires (resulting from lightning strikes)

Human Caused Risks

- Dangerous Goods Incidents
- Forest Fires/Fires (resulting from human activity)
- Public Health Incidents
- Explosion

These are just a few of the many risks that may confront Manitoba communities.

The Emergency Plan

After considering the risks and recognizing what constitutes an emergency, it is recommended that a community develop an Emergency Plan. In fact, it is now required by law that a community prepare a plan. This is a new provision of The Emergency Measures Act passed in 1987. The plan will spell out procedures and responsibilities and should serve to aid in the coordination of an overall emergency response. Thus, one of the first steps in developing a plan is to define the purpose of the plan. The purpose or aim of the plan is a fairly simple statement against which you measure the ensuing detail of the plan. If subsequent provisions in the plan support the purpose they belong in the plan. If they don't, you omit them from the plan.

Some of the risks which a community may face can occur with abundant warning. Unfortunately some emergencies or disasters afford little or no warnings. In situations with ample time for warning, the plan should specify the arrangements for receiving the warning. Upon receipt of a warning with time to react, the plan should specify who will react and what actions they may take to further disseminate the alert. This alert system will indicate channels of notification and responsibilities for action.

Upon becoming aware of an emergency the community must undertake actions to control it. Control of the emergency through implementation of the plan is handled by a group of responsible community members collectively referred to as the Emergency Response Control Group. This should include individuals such as the mayor, council members, and the community emergency co-ordinator. This group is separate from the On-Site Emergency Response Operations Team. As the title suggests, this latter group consisting of police, fire and ambulance services representatives, deals directly with emergency mitigation activities on-site. Lists of duties should be developed for each key participant in both groups and should be included in the plan.

As part of the overall emergency response, the community may have to designate an Emergency Operations Centre which will contain the Control Group from which they will coordinate the activities of the on-site Emergency Response Operations Team. Frequent Emergency Operations Centres are located in the Town Hall/Municipal Offices.

The Emergency Operations Centre (EOC)

An EOC is the nerve centre for any emergency response activity. It serves at least five major functions:

1) Coordination - This is one of the important functions of an EOC and it is accomplished through good communications and quality information.

2) Decision-Making - Accurate information is also a key to sound decisions. To make necessary decisions during an emergency someone must be in charge. In many communities this is either

the Secretary-Treasurer or Emergency Coordinator. For high-level decisions, the Mayor, Reeve or Councillors will obviously need to be available and involved.

3) Operations - An EOC should be a well organized work area complete with necessary office equipment, desks, etc. and essential communications equipment and maps. The EOC should be separate from other areas where normal municipal activities may continue during an emergency. It is also important to consider the security of the EOC, so that operations may be conducted with minimum interference from other civic employees and the public.

4) Information - During an emergency information must be gathered and disseminated. It is imperative that the public be kept informed. Accurate and timely information is also essential for aiding decision-makers. Communications are inevitably the most critical aspect of emergency management. Very little can be coordinated without a good communication plan and equipment.

5) Visitor Control - Concerned and curious citizens, VIP's, officials from neighboring communities and others will often converged on an EOC. The media will also be requesting news, facts and figures, along with the latest information. The appearance and management of these people must be handled in a way which will not jeopardize the efficiency of the EOC. Close cooperation with the news media is an important key to a positive and beneficial relationship.

The nature of each community will determine who will be involved in the EOC operation. The following of potential participants should be considered:

- Elected Officials and Secretary-Treasurer
- Public Safety - Police, Fire, Ambulance/Medical
- Public Works - Utilities, Engineers
- Social Services - Red Cross, Salvation Army, etc.
- Public Health - Hospitals, Medical Examiner, Funeral Homes
- Public Information - Media, Postal Services
- School Liaison

There are no hard and fast rules governing the establishment and operation of an EOC. Every emergency is unique and each community has its own set of circumstances. If a community has an emergency, a well organized and effective EOC is essential to maximize response efforts.

Exercises

The development of an emergency plan and the designation or establishment of an EOC are only part of the complete emergency preparedness picture. An effective program will also include an ongoing schedule of exercises which will permit the testing and refinement of the plan along with other essential components such as the EOC.

Exercises comprise one of the most effective ways to prepare for an emergency or disaster. Many Manitoba municipalities have already discovered the value of this important component of emergency preparedness. Community exercises can be coordinated with other local facilities, such as the hospital, to assess overall readiness to respond to disaster situations. Significant benefit can also be realized from conducting paper or table-top exercises. A paper exercise is one where people role play. In this instance the response is simulated, perhaps by officials in one building using internal telephones, intercom or radio units. This type of

paper exercise is usually sufficient to evaluate a new municipal emergency plan.

All exercises, whether actual mock disasters or paper exercises require thorough planning and coordination. The most important element of the planning process is the selection of a realistic exercise scenario. Maximum benefit will be realized by selecting emergency situations that are most likely to occur in a given community. The risk assessment, mentioned previously, is useful in revealing a plausible scenario.

A successful exercise should help to answer questions such as:

- Does the warning system outlined in the plan work?
- Do key personnel understand the plan?
- Is the Emergency Response Control Group properly organized?
- Are the emergency plans of all community agencies up-to-date?
- Have contact persons or phone numbers changed?

It is critically important to have these sorts of questions answered by an exercise, rather than a real emergency.

Conclusions

Emergency preparedness is a multi-faceted procedure with many components. This paper has outlined only the key components and it cannot be over-emphasized that a comprehensive approach is best. Emergency preparedness begins with a keen awareness of the types of emergencies that may be faced. It involves the establishment of concise response plans which clearly establish procedures. What must be done? Who has what responsibilities? Those individuals with specific skills and abilities (i.e. police, fire, etc.) must be recognized in the plan. The plan should stipulate how and when they will be alerted. Once established, plans must be coordinated with one another. They must be kept up-to-date and they should be refined and improved through an ongoing program of exercises.

There are, however, other key elements important to emergency preparedness which haven't been discussed in this planning paper. Not the least of which is training and education to acquaint community responders with advances in methodology. Advice on all of these topics is available from the provincial Emergency Measures Organization.

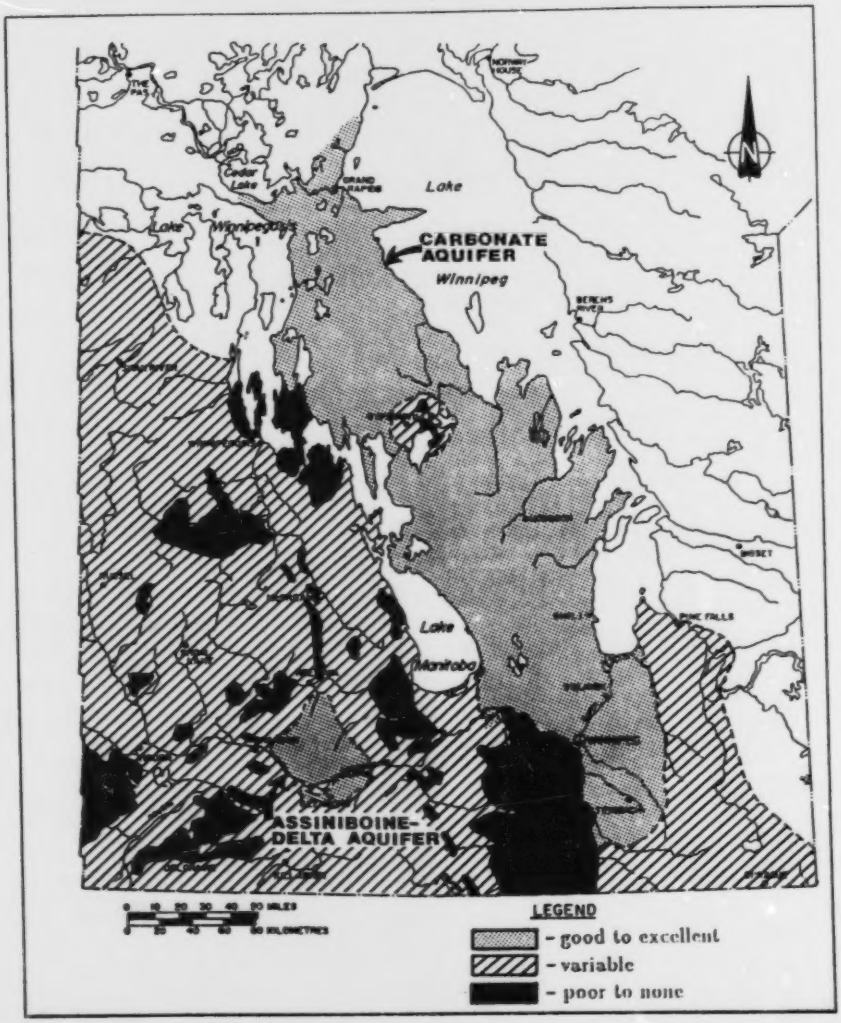
GROUNDWATER AS A SOURCE OF MUNICIPAL WATER SUPPLY IN MANITOBA

Lockhart Grey, P.Eng.
Manitoba Water Resources Branch

GROUNDWATER AVAILABILITY

To be used successfully for municipal water supply purposes groundwater must be available in suitable quantity and quality. A general appreciation of the availability of groundwater in Southern Manitoba can be gained by looking at the groundwater potential as shown in Figure 1. Southern Manitoba is blessed with two areas, shown in pink, with good to excellent groundwater potential in terms of both quantity and quality. Excellent groundwater in the south central area is derived from thick saturated sand deposits of glacial origin known as the Assiniboine Delta Aquifer. In the eastern area excellent groundwater is derived from thick saturated deposits of carbonate rock known as the Carbonate Aquifer. By contrast the areas shown in red have essentially no usable groundwater.

FIGURE 1
General Availability of Groundwater for Municipalities



The rest of Southern Manitoba is characterized by variable groundwater potential, shown in green, which means that numerous small aquifers containing fresh groundwater are present. Where variable groundwater potential exists skillful exploration is required to define aquifers that are capable of satisfying municipal needs. It is in this area that the greatest number of groundwater sources have been successfully developed to meet a wide variety of municipal needs. Much of this success can be attributed to the comprehensive exploration program carried out by the Manitoba Water Services Board.

TYPES OF MUNICIPAL USE

Since the advent of the Manitoba Water Services Board in 1959, the exploration of groundwater sources to meet municipal needs has been pursued quite vigorously. This has led to considerable expansion in both the number and type of municipal water supply systems in Manitoba as shown in Table 1. Today, there are over 50 conventional municipal water supply systems servicing individual committees that use groundwater as a source of supply. A relatively new concept in municipal water supply systems is regional pipelines that serve a number of communities from a single source. The first such system using groundwater as a source is currently in the planning stage and would use water from the Assiniboine Delta Aquifer to supply the communities of Gladstone and Plumas.

TABLE 1
Types of Groundwater Use by Municipalities

1. Conventional Water treatment and Distribution Systems
   - single community
   - multi-community (regional pipelines)

2. Non-Conventional Water Supply Systems
   - loading stations
   - individual household wells with common sewage collection system

3. Conversions from Surface Water Systems
   - Russell
   - Ste. Rose
   - Selkirk

The drought experience in 1961 led to the development of groundwater sources to supply municipal loading stations from which rural residents haul water for a variety of needs including domestic, livestock and sprayer application of agricultural chemicals. The low suspended solids associated with groundwater loading stations makes them particularly attractive for use in sprayer application of agricultural chemicals. The General Manager of the Manitoba Water Services Board has indicated that by the end of 1988 there will be more than 150 municipal loading stations in Manitoba.

Another type of municipal use that is employed by a number of communities, particularly in areas where groundwater potential is good to excellent, is the use of individual household wells combined with a common sewage collection and treatment system. Some fairly large communities including Birds Hill, Oak Bank and Teulon utilize this type of system. Quality control of individual household wells is a problem since generally no formal approval system exists in Manitoba for private domestic wells.

The general success of groundwater as a source of municipal water supply in the 1960's and the 1970's has led some communities to convert from surface water sources to groundwater sources. Notable examples are the Towns of Russell and Ste. Rose du Lac. The Town of Selkirk has the distinction of switching from a groundwater source to a surface water source and back to a groundwater source. Low reservoir levels caused by the 1988 drought has prompted the Town of Boissevain to look at the feasibility of developing a groundwater source to meet their municipal needs.

PERFORMANCE OF GROUNDWATER SOURCES

In view of the number of municipal water supply systems in Manitoba that use groundwater, it is appropriate to look at the performance of some of the groundwater sources (aquifers). Table 2 shows the nature of the groundwater development and the performance of the aquifer for a number of selected municipalities. With the exception of Hartney, the municipalities in Table 2 have been selected to demonstrate various types of aquifer performance problems that have been encountered in Manitoba.

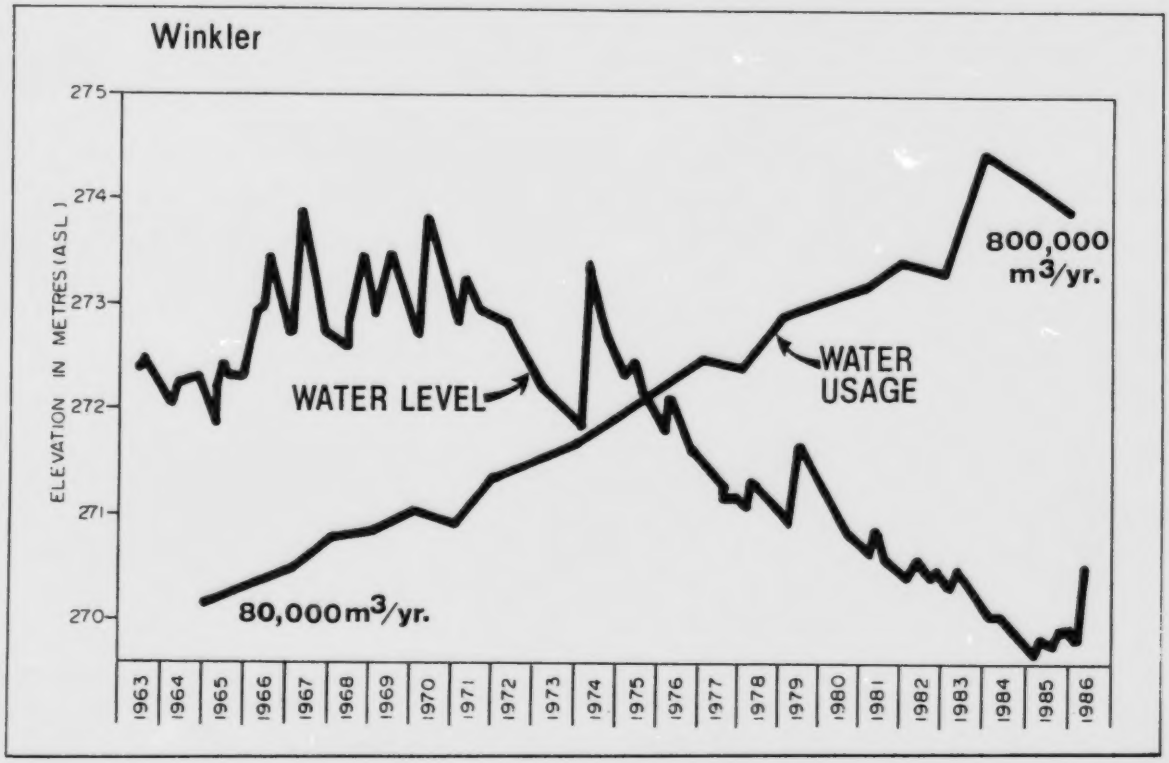
TABLE 2
Aquifer Performance Municipal Use

Municipality	Aquifer Development		Aquifer Performance
	Production Well	Observation Well	
Hartney	1-(1961)	2-(1962) 1-(1966)	- trouble free
Winkler	2-(1963) 1-(1967) 3-(1968) 2-(1981) 2-(1988)	1-(1962) 2-(1963) 2-(1966) 5-(1968) 7-(1981) 2-(1982)	- water level decline
Baldur	1-(1966) 1-(1975)	1-(1966) 1-(1973) 1-(1974)	- water level decline
Elie	1-(1968) 1-(1984)	1-(1964) 3-(1981) 5-(1983)	- chloride contamination
Oakville	1-(1973) 2-(1978) 2-(1983)	1-(1964) 1-(1980)	- nitrate contamination
Stonewall	2-(1975) 2-(1980) 1-(1987)		- nitrate contamination
Birds Hill	1/house	1-(1965) 1-(1979)	- gasoline contam., drought related well failures

Declining water levels is an aquifer performance problem that has developed at Baldur and Winkler. This type of problem stems from the fact that withdrawals from the aquifer exceed recharge to the aquifer. Figure 2 shows the nature of the water level decline that has been recorded for the Winkler Aquifer.

FIGURE 2

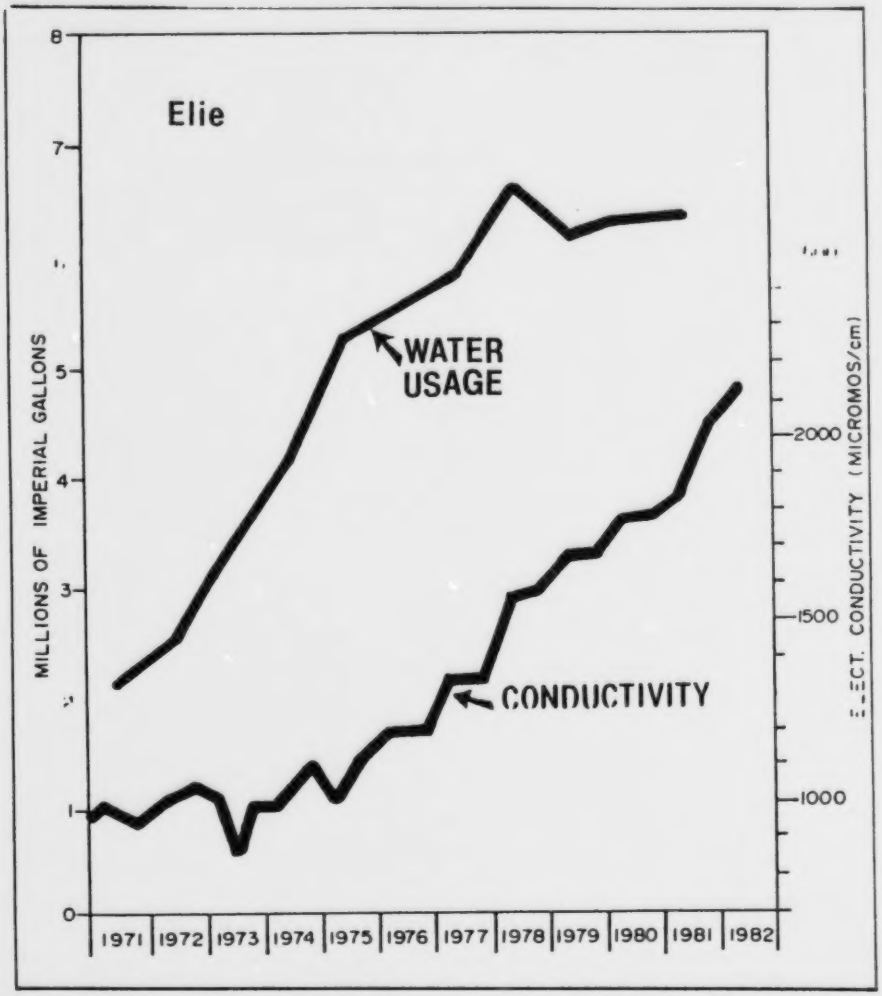
Winkler - Water Level Decline



Chloride contamination is an aquifer performance problem that can develop in fresh water aquifers that are hydraulically connected to salt water aquifers. This type of aquifer relationship is common in the Red River Basin of Manitoba. The nature of the chloride contamination associated with the aquifer supplying water to the Elie municipal system is shown in Figure 3.

FIGURE 3

Elie – Chloride Contamination



Nitrate contamination is an aquifer performance problem that has effected the municipal water supply systems at Oakville and Stonewall. In both cases nitrate levels in production wells increased over a period of time to levels that exceeded the maximum acceptable level for domestic consumption and resulted in the shutdown of the production wells. Figure 4 shows the nature of the nitrate contamination associated with the Oakville municipal water supply system.

Gasoline contamination is an aquifer performance problem that has affected a number of individual household well water supply systems in the community of Birds Hill. The unconfined nature of the aquifer system in the Birds Hill area makes the aquifer vulnerable to the migration of contaminants from the land surface to the water table (the upper surface of the aquifer). Once contaminants enter the aquifer they tend to move in the direction of regional flow in the aquifer. The general pattern of gasoline contamination in the Birds Hill area is shown in Figure 5.

FIGURE 4
Oakville – Nitrate Contamination

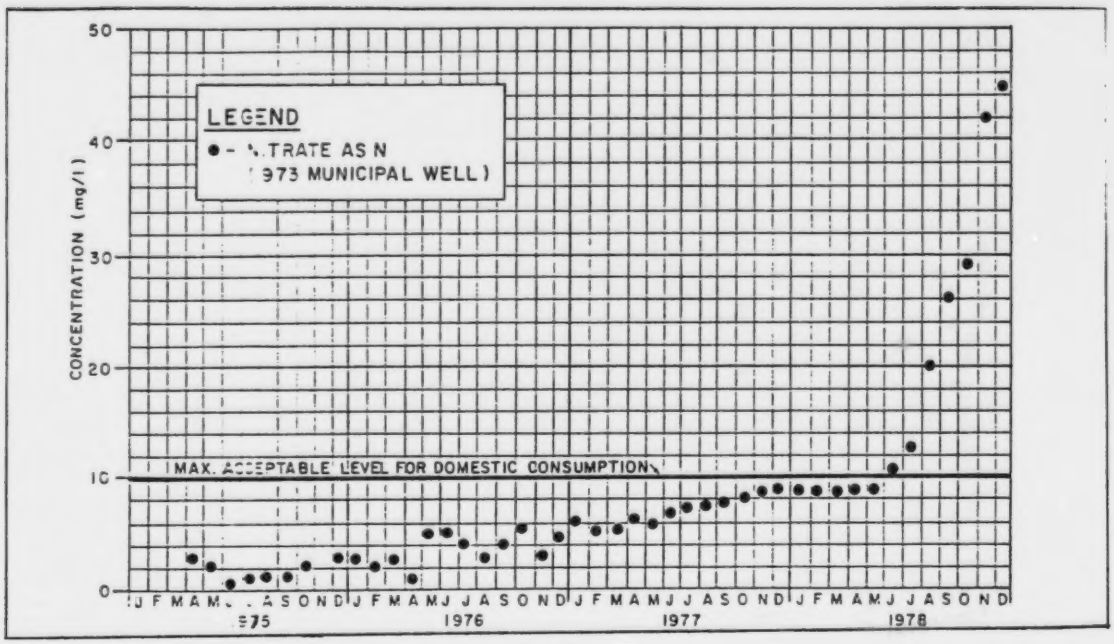
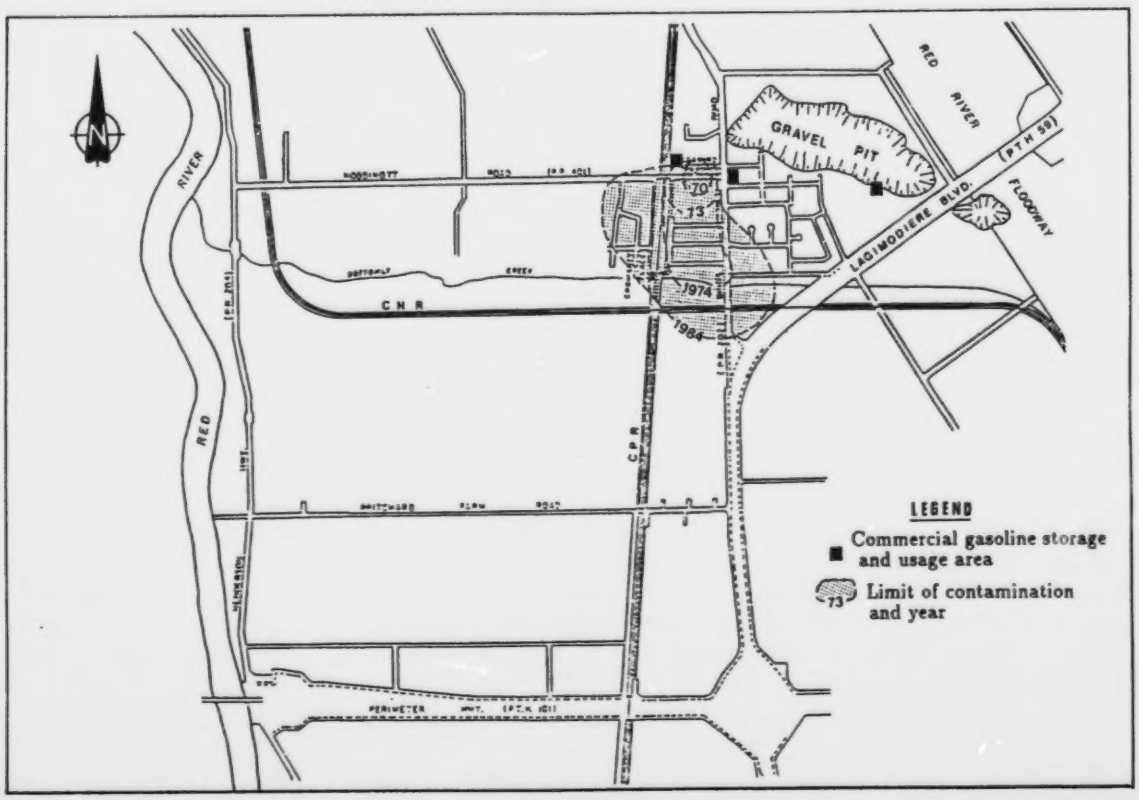

LEGEND
● - NITRATE AS N
(1973 MUNICIPAL WELL)
CONCENTRATION (mg/l)
50
40
30
20
10
0
MAX. ACCEPTABLE LEVEL FOR DOMESTIC CONSUMPTION
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1975
1976
1977
1978

FIGURE 5
Birds Hill – Gasoline Contamination



Another aquifer performance problem that surfaced during the 1988 drought involved the failure of individual household well water systems in a number of communities including Birds Hill, Oak Bank, Ste. Anne and Teulon. This problem stems from the combined effect of increased withdrawals locally and results in a local depression of the water levels in the aquifer. This type of problem could become more severe as these communities grow and the local demand for groundwater increases particularly during peak demand periods.

AQUIFER DETERIORATION REMEDIES

A number of remedies to correct aquifer performance problems have been investigated and/or applied in Manitoba to deal with both quantity deterioration and quality deterioration as shown in Table 3.

TABLE 3
Aquifer Deterioration Remedies

1. Quantity Deterioration
   - Baldur ..... artificial recharge
   - Winkler ..... artificial recharge (conceptual)

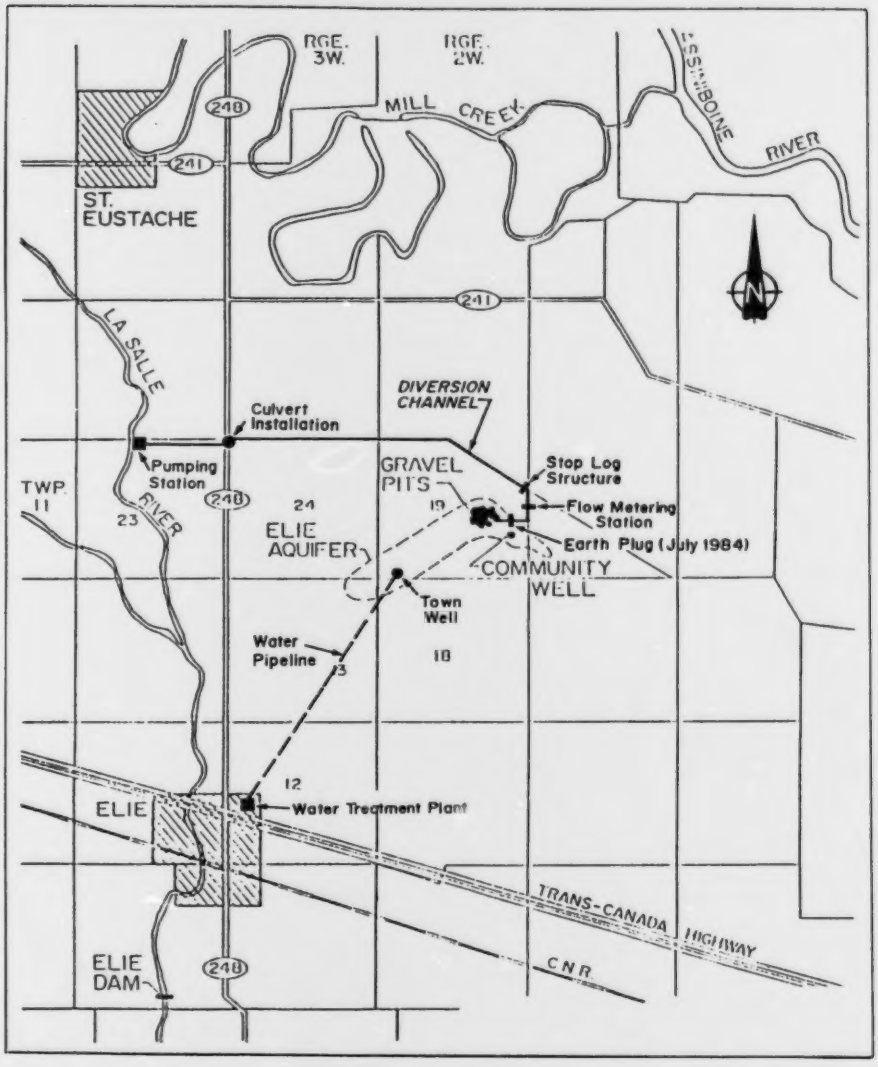
2. Quality Deterioration
   - Elie ..... artificial recharge (experimental)
   - Oakville ..... horizontal separation
   - Stonewall .... vertical separation
   - Birds Hill ... individual discretion

Water quality deterioration problems have been experienced by conventional municipal water supply systems at Baldur and Winkler and by non-conventional municipal water supply systems at Birds Hill, Oak Bank, Ste. Anne and Teulon.

At Baldur the limited capacity of the aquifer was recognized prior to its development, but development proceeded since the aquifer was the only viable fresh water source available to the community. As water levels declined in the aquifer at Baldur attempts were made to artificially recharge the aquifer by transferring water from nearby surface water bodies to the ground surface in the vicinity of the municipal production well using a temporary pump and piping system. This makeshift method was successful in stabilizing declining water levels in the aquifer and has been used periodically for several years.

At Winkler the capacity of the aquifer initially was adequate to meet the needs of the municipal system. However, rapid growth in the Town of Winkler resulted in a tenfold increase in water withdrawals from the aquifer between 1965 and 1986. This increase in withdrawal rate coupled with that of other users has resulted in declining water levels. The Winkler Aquifer like the Elie Aquifer is located in the lake plain region of the Red River Valley which receives considerable runoff from the escarpment to the west. This watershed circumstance is relatively ideal for making transfers of runoff water from surface water courses to the aquifer. The concept of artificially recharging the aquifers at Elie and Winkler to enhance their potable water capacity is being evaluated. At Elie, a system to transfer water from the La Salle River to the Elie Aquifer was established for experimental use in 1983 as shown in Figure 6. The transfer system at Elie has not been used because unacceptable levels of agricultural chemicals were found in the water in La Salle River.

FIGURE 8
Artificial Recharge Remedy



In the case of individual household well failures at Birds Hill and other communities with similar water supply systems remedies are somewhat at the discretion of the individual well owner. In most cases modification of the pumping system and/or the well can restore the water supply. This type of water supply problem is particularly difficult since withdrawals from private domestic wells are generally not subject to any form of approval or regulation as is the case with conventional municipal water supply systems.

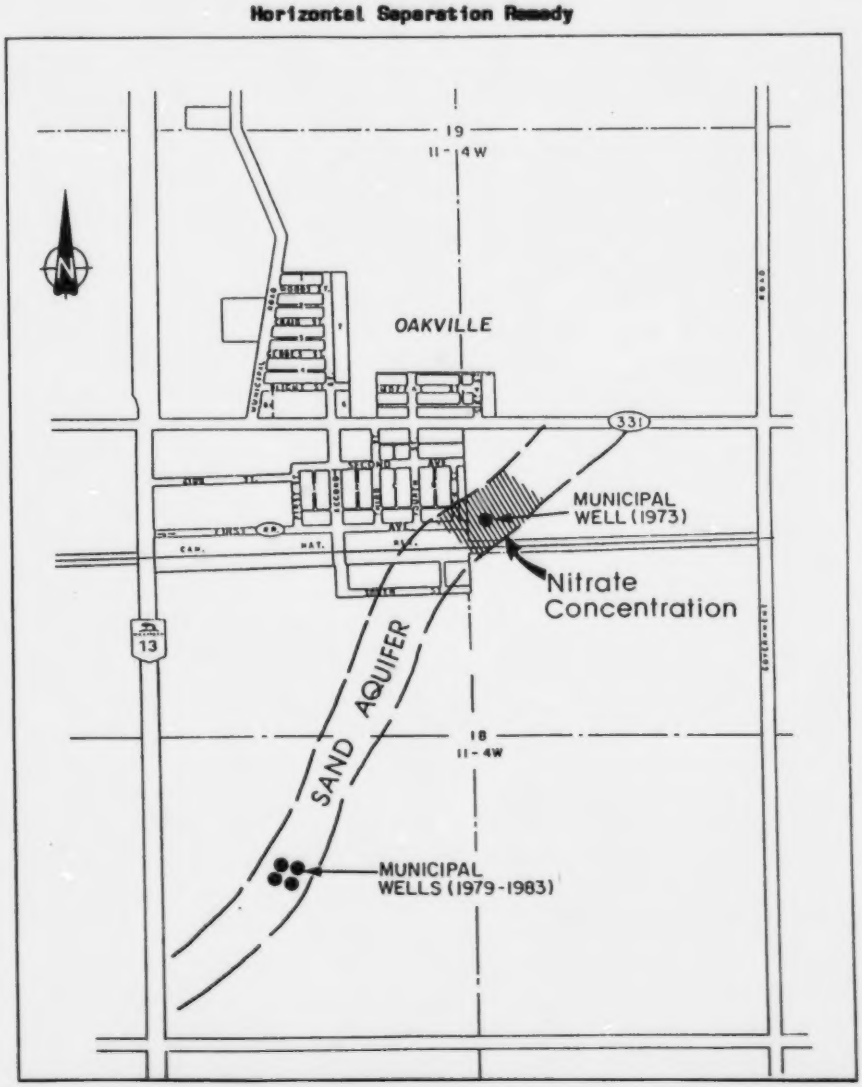
Water quality deterioration problems associated with groundwater sources have been identified at Elie, Oakville, Stonewall and Birds Hill and include contamination by chloride, nitrate and gasoline.

The chloride concentration at Elie results from the fact that the aquifer used to supply the municipal water system is essentially a local mound of freshwater with limited natural recharge that floats on a regional saltwater aquifer. Supplementing the natural recharge to the freshwater aquifer with water transferred from the La Salle River is being considered as a means of increasing the water supply capability of the aquifer and reducing the encroachment of saltwater from the base of the aquifer.

The nitrate contamination at Oakville and Stonewall is believed to result from local land use activities including domestic waste disposal and the application and/or accidental spillage of agricultural chemicals. Different remedies have been implemented to correct the problem at these two communities.

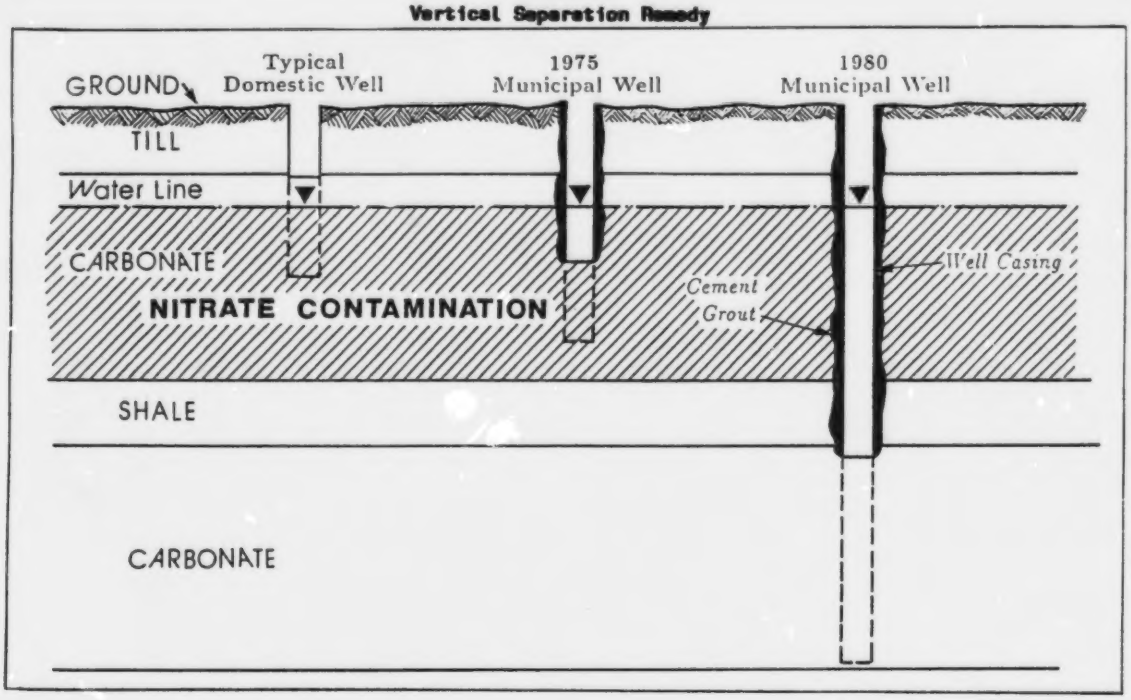
At Oakville the solution to the nitrate contamination problem was to develope a new production well in the same aquifer at a safe horizontal distance from the contaminated well. The location of the production wells at Oakville is shown in Figure 7.

FIGURE 7
Horizontal Separation Remedy



At Stonewall the solution to the nitrate contamination was to develop a new production well that draws water from a deeper aquifer separated vertically from the contaminated aquifer by an impervious shale layer as shown in Figure 8. This solution is somewhat fragile in that it depends on carefully constructed wells to maintain the integrity of the shale layer to separate the contaminated aquifer from the uncontaminated aquifer.

FIGURE 8
Vertical Separation Remedy



At Birds Hill no concentrated effort has been made to solve the gasoline contamination problem. Many households have had to put up with the odour of gasoline in their well water for extended periods of time.

AQUIFER MANAGEMENT CONSIDERATIONS

The experience gained from utilizing groundwater sources for municipal water supply systems in Manitoba has heightened our awareness of both the requirements and the opportunities for successful aquifer development. The level of aquifer development achieved has forced our Department to focus on the aquifer management considerations shown in Table 4. To achieve optimum utilization of the groundwater sources in the province effective programs will have to be developed to deal with each of these elements of aquifer management.

TABLE 4
Aquifer Management Considerations

1. Monitor aquifer performance
2. Correct aquifer deterioration
3. Maintain sustainable development

It has long been recognized that the mechanical components (pumps, valves, etc.) of municipal water supply systems need to be monitored to ensure they are functioning properly, that corrective action needs to be taken when malfunctions occur and that general plant upgrading is required from time to time to ensure satisfactory performance of the system. This recognition is reflected in the plant maintenance program, the annual operating cost of the plant and in the price consumers pay for the water they use.

Something that is not well recognized is that all municipal water supply systems are dependent on various components of the hydrologic cycle to provide a basic ingredient: a dependable supply of raw water. We are particularly aware of this fact during periods of drought. Our experience with the utilization of groundwater sources has demonstrated the need for monitoring aquifer performance, correction aquifer deterioration, and implementing aquifer enhancement projects where feasible. This lack of recognition is reflected in the vagueness of hydrologic system maintenance programs, their annual operating cost, and the price the consumer pays.

IMPLEMENTING YEAR-ROUND CHEMICAL COAGULATION AT THE CITY OF CALGARY'S WATER TREATMENT PLANTS

R.T. Seidner, E.E. Hargesheimer, C.M. Lewis, T. Satchwill
City of Calgary
Engineering Department

INTRODUCTION

Until 1987 the City of Calgary employed chemical coagulation at its two conventional water treatment plants only during periods of elevated raw water turbidity. Such periods occurred during spring runoff, rainstorm events and occasional algae blooms. For the remainder of the year which generally ran from late summer through spring break up, raw turbidity stayed well below 1 NTU. Drinking water quality problems associated with the lack of chemical coagulation were never detected: daily tests for total coliforms and monthly tests for Giadia cysts were always negative in the finished water. Indeed, the practice of discontinuing chemical coagulation during low turbidity periods was common at many Rocky Mountain utilities[1].

Nevertheless, a need to critically review the practice of filtration without chemical pretreatment evolved in 1985. Concern that chlorine resistant microbiological contaminants (particularly Giardia cysts which are endemic to surface waters of the Rocky Mountains) were passing through treatment processes was growing. As a result the role of chemical coagulation advanced as a key step in filtration (1,2,3). Also, leading regulatory agencies, notably the United States Environmental Protection Agency, were closely examining considerably tighter turbidity goals such as the 0.1 NTU recommended maximum contaminant level (5). To achieve such a goal would require chemical pretreatment. In 1986 the City of Calgary was advised by its regulatory authority Alberta Environment to examine the feasibility of implementing chemical coagulation as a year-round treatment strategy.

An initial review (1986) of water treatment literature revealed that chemical coagulation of low turbidity water had not been thoroughly studied particularly in low temperature ranges. Previous studies investigated high alum doses (50 mg/L) (1) and added turbidity prior to chemical coagulation (5). One pilot plant study suggested that a combination of alum and polyelectrolyte was required for 95-99% Giardia removal in low temperature (3-4°C) water (2). Ferric salts due to their low solubility near pH 8.3 might exhibit advantages over alum for low temperature low turbidity situations (7). Although charge neutralization behavior was well understood for the classical flocculated situation (8), the specific low turbidity low temperature case had not been elucidated mechanistically. Thus, dose strategies suggested were based on surrogate measurements such as percent turbidity removal or percent coliform removal (3).

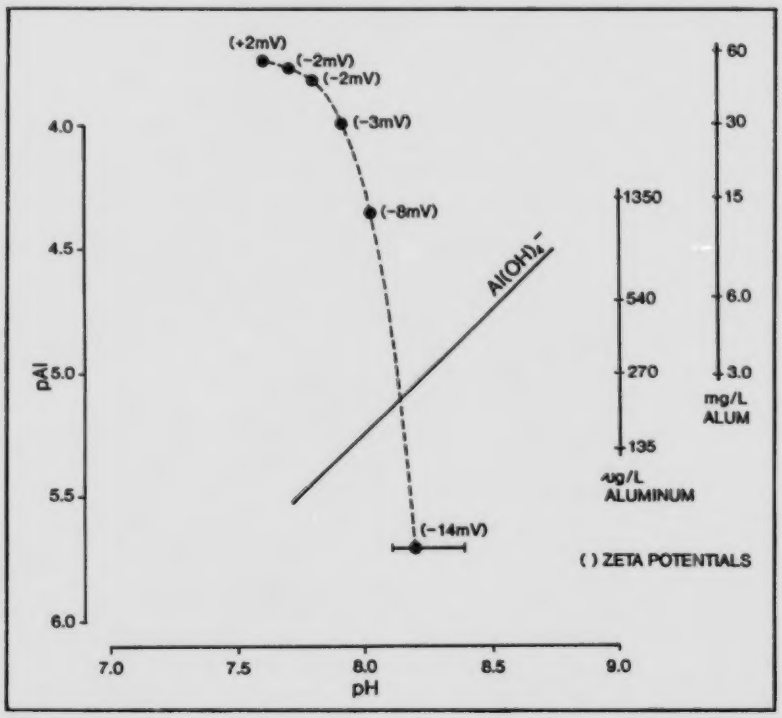
Due to a shortage of background knowledge it was concluded that a reasonably comprehensive investigation should be undertaken. Not only did various coagulants and their dose range need to be explored but a means to optimize and control doses also needed to be defined. In addition, there was a need to address possible adverse effects on finished water and the treatment process. Enhanced corrosion and higher aluminum concentrations were of concern. Bacterial sloughing was also seen as a possibility because of reports of pH induced coliform biofilm sloughing in distribution systems (9). Starting in December 1986 a program to explore all these facets of chemical coagulation was undertaken, firstly at bench scale, then at pilot scale and finally at plant scale.

RESULTS AND DISCUSSION

BENCH SCALE. Laboratory experiments on the low turbidity water yielded only limited information. Classical jar tests did not enable differentiation between alum doses less than 50 mg/L. Simple titration and associated measurements of the low turbidity water with alum were more useful (Figure 1). The zeta potential associated with each alum dose suggested that low alum doses should be sufficient to achieve adequate particle destabilization. Previous plant scale experience at higher turbidities had shown that a zeta potential of -10 mV provided optimum filtration. For the low turbidity case, this zeta potential could be achieved at less than 10 mg/L alum. Unfortunately, the large variances associated with measuring zeta potentials on low concentrations of particles precluded its use as a precise dose setting tool (10). The titration displayed a pH shift of approximately -0.02 pH unit per mg/L alum dose. The intersection of the alum titration curve with the 0°C solubility plot of $Al(OH)_4^-$ (11) indicated that at least 3 mg/L alum would be needed to exceed the solubility product and effect charge destabilization (Figure 1).

FIGURE 1

Titration of Low Turbidity Raw Water with Alum
Aluminum Hydroxide Solubility Product at 0° Taken from Reference 11



PILOT SCALE. A 0.016 ML/day pilot plant which was a scaled down version of the City of Calgary's Glenmore Water Treatment Plant was used to test a variety of chemical coagulants (Table 1)(10,12). Initial experiments focused on alum since it was already in use at both full scale plants for the high turbidity periods. These experiments showed that enhanced turbidity removal could be achieved with 5 to 10 mg/L alum dosing. Little variation in finished water turbidity within this dose range was observed. At the upper end of the dose range the filter runs tended to be less consistent.

TABLE 1

Coagulants and Doses Used in Pilot Scale Filtration Studies

Coagulant	Doses Ranges
Aluminum Sulphate	5-30 mg/L as a primary coagulant, 3.5-15 mg/L combination with polymers
Polyaluminum Chloride	1-25 mg/L as a primary coagulant, 1-5 mg/L in combination with polymers
Ferric Sulphate	5 mg/L as a primary coagulant
Cat Floc T	0.3-0.9 mg/L as a primary coagulant, 0.3-1.0 mg/L in combination with aluminum sulphate
Percol LT31	0.3 mg/L as a primary coagulant, 0.25-0.5 mg/L in combination with aluminum sulphate
Alchem 603	0.2-0.5 mg/L in combination with aluminum sulphate
Alchem 8103	0.2-0.5 mg/L in combination with polyaluminum chloride

Later experiments showed similar turbidity removal with ferric sulphate, polyaluminum chloride and several mixed combination of metal salts and cationic polyelectrolytes of higher molecular weight (Table 2). Finished water aluminum levels were highly variable although there was an association between the higher aluminum levels and higher loading of aluminum in the coagulant. When the molar loading of aluminum was reduced by combining alum with polyelectrolyte a reduction in finished water aluminum levels was observed. Sudden turbidity changes in response to doses or dramatic differences among results were not observed. Turbidity as a whole seemed to reflect a plateau effect - a specific level of enhanced turbidity removal which pertained to a fairly wide dose and coagulant range. This observation could well be a measurement artifact due to loss of resolution as the measurement system approaches the detection limit. In addition turbidity measurement reflects various physical properties of the particulates causing a "blend" in values particularly at such low values.

TABLE 2

Selected Optimum Turbidity Results from Pilot Scale Studies

Coagulant	Dose (mg/L)	Turbidity (NTU)
Ferric Sulphate	5	0.10
Alum	10	0.07
Polyaluminum Chloride	3	0.08
Alum	5	0.07
Cat Floc T	0.3	
Polyaluminum Chloride	2	0.07
Cat Floc T	0.6	

PLANT SCALE. After completion of the first pilot scale runs with alum, an initial series of week long tests at the Glenmore Water Treatment Plant at 5 mg/L and 10 mg/L alum was conducted under winter conditions (Table 3). Both these tests resulted in enhanced turbidity removal. Finished water turbidity near 0.1 NTU was very similar to what had been achieved in the pilot scale study. Also similar to the pilot scale run, little difference in final turbidity from the two doses was observed. Settled water turbidity always was slightly higher than raw water turbidity indicating that little if any flocculation/settling was occurring. It was concluded that the enhanced turbidity removal was largely due to filtration. Some cases of filter instability at the higher alum dose were observed which could also be attributed to the direct filtration mechanism. On the basis of these preliminary trials year-round chemical coagulation based on 5 mg/L alum dosing was initiated. This was substantially less than typical doses (15-30 mg/L) used during high turbidity episodes.

TABLE 3

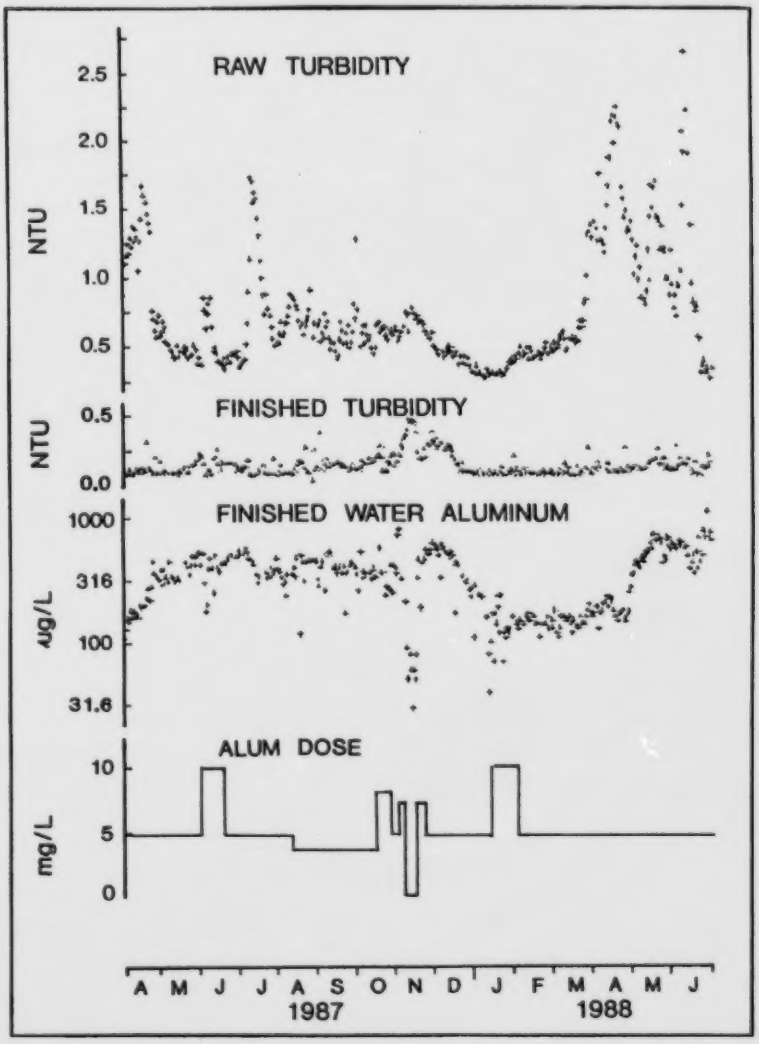
Initial Week Long Alum Tests at the Glenmore Water Treatment Plant at Low Temperature and Low Turbidity

Date	Average Alum Dose (mg/L)	Average Raw Water Temp. (0^{0})	Average Raw Water Turbidity (NTU)	Average Finished Water Turbidity (NTU)
Dec 25-31/86	0	1.1	0.43	0.30
Jan 6- 8/87	10	1.2	0.47	0.11
Jan 10-19/87	0	1.2	0.47	0.29
Jan 20-30/87	5	1.2	0.57	0.09
Feb 1- 7/87	0	1.7	0.55	0.33

Both water treatment plants in Calgary have been operated with alum pretreatment since April 1987. Dosages ranged between 4 mg/L and 10 mg/L (the normal episodes of high raw water turbidity did not occur in this period). There was one brief period of no alum pretreatment at one plant. Figure 2 shows alum doses, finished water aluminum concentrations and turbidities at the Glenmore Water Treatment Plant for April 1987 through June 1988.

FIGURE 2

Alum Doses, Aluminum Concentrations in Finished Water, Raw Water Turbidity and Finished Water Turbidity at the Glenmore Water Treatment Plant April 1987 to June 1988



Enhanced turbidity removal was achieved throughout the treatment period with the plant easily producing finished water of turbidity between 0.1 and 0.2 NTU. The grand average of finished water turbidity was 0.14 NTU and represented an 82% turbidity removal. Most excursions into the 0.5 NTU region were associated with dose manipulations though occasional values near 0.25 NTU were observed.

Aluminum concentrations in the finished water were elevated considerably above raw concentrations of 20 to 80 ug/L. The overall finished water average of 340 ug/L placed at the 80th percentile of North American filtered water supplies recently surveyed (14). A "loading up" effect could be discerned after initiating the alum dosing on April 1, 1987. High aluminum in finished water has typically been attributed to particulate breakthrough (14). However, it can be seen that (with the exception of December 1987) the periods of higher aluminum concentrations did not correlate with higher turbidity periods. It may be that complexing with high bicarbonate (up to 220 mg/L) or other anions increased solubility well above that predicted by its solubility product (Figure 1). That being the case, future control measures would center on reducing the aluminum in the coagulant dose employed.

Of initial concern were possible effects of the constant pH shift caused by year-round alum treatment. It was postulated that the -0.1 to -0.2 pH shift could promote both corrosion and bacterial sloughing in the distribution system. Small shifts in pH just due to increased chlorine doses were responsible for coliform biofilm sloughing in another distribution system (9). Such effects would be particularly pertinent in the winter when the saturation index tended toward undersaturation (Figure 3). To test this postulate one month runs at two dose rates (5 mg/L and 10 mg/L) were conducted in the winter of 1988 to see any dependence of corrosion and bacterial contaminants on dose rates. At the end of the run periods the postulated effects were sampled for with the routine distribution system metals and bacterial monitoring as well as a "first draw" protocol. While a first draw protocol has considerable variances associated with individual plumbing systems, it does target the sought for effects (15). Nineteen pairs of samples from homes throughout the City of Calgary were collected during the two dose rate runs. A statistically significant difference in copper concentration was evident (Figure 4) but the difference was not of a magnitude to be of concern. Also, there was no statistical difference in bacterial results from the two dose rate runs. Thus, it was concluded that meaningful effects from the pH shift were not occurring.

FIGURE 3
Langelier Saturation Index of Finished Water from the Glenmore Water Treatment Plant 1984-1986

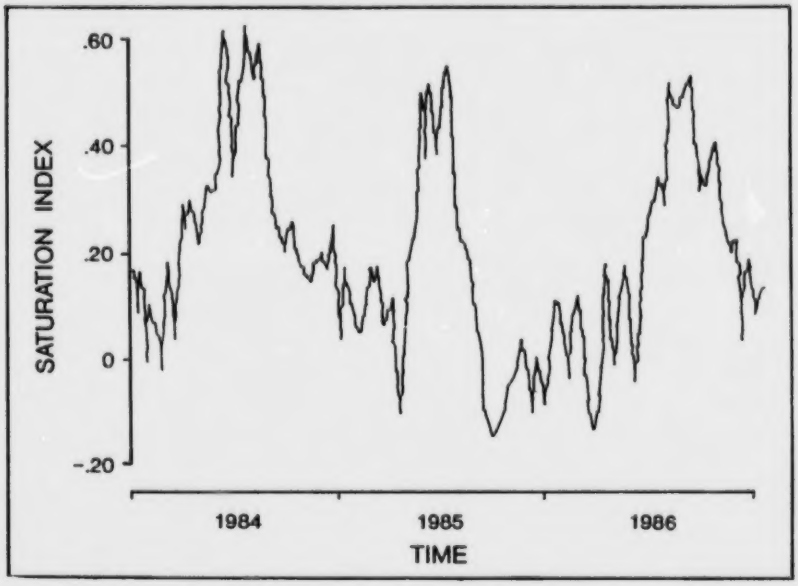
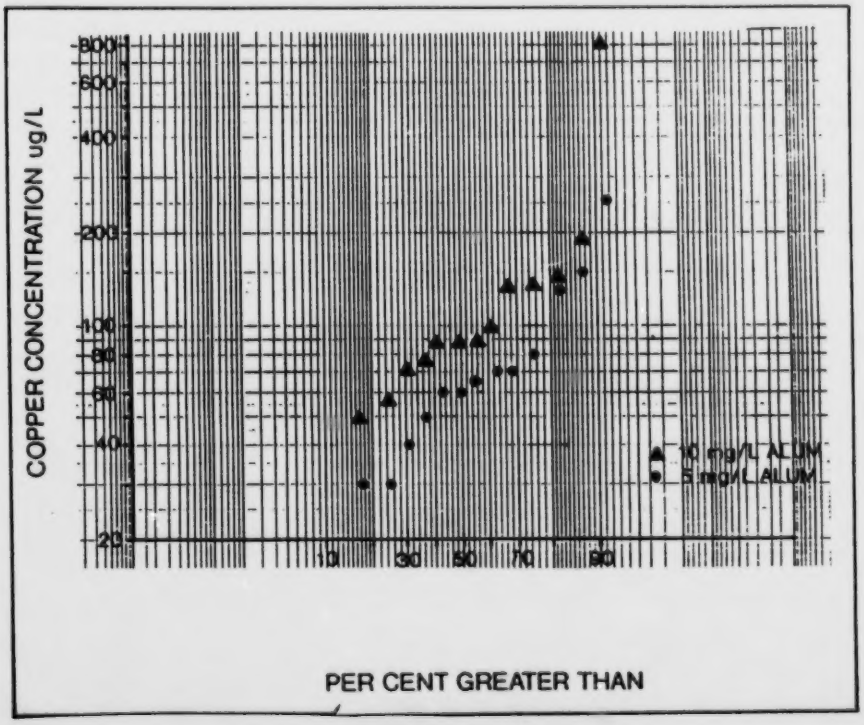
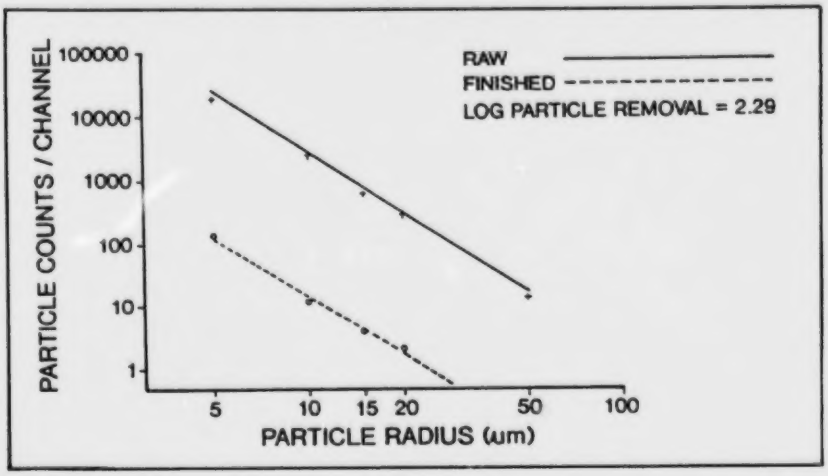


FIGURE 4
Copper Concentrations in First Draw Samples from Homes after One Month 5 mg/L Alum Dose and after One Month 10 mg/L Alum Dose (January and February 1988)



Particle size analyses provided reasonably definitive information on both pilot and plant scale runs. Logarithmic plots of particle concentrations verses particle radii were linear (10). These plots (Figure 5) could be used to evaluate size ranges of interest (e.g. for Giardia one would examine removal achieved at radius 7 um) or to calculate overall removal effectiveness in log units.

FIGURE 5
Particle Size Analysis of Glenmore Water Treatment Plant Water at 5 mg/L Alum Dosage



Actually particle size analysis proved considerably more sensitive than turbidity in differentiating effects of various coagulants and their doses at both pilot and plant scale. Turbidity measurements lose ability to determine differences near 0.1 NTU. This might be a simple detection limit phenomenon where the region near the detection limit can only be utilized for qualitative work (presence/absence)(16). It may also be due to the varying array of factors (particle populations, sizes, shapes, colors, etc.) that ultimately lead to each measurement. Whatever the cause, a general non-sensitivity of turbidity to dose changes was observed whereas a clear change in particle size distributions was observed (Table 4). Furthermore, these size distributions provided much more physical information on doses than an index such as turbidity could.

TABLE 4

Comparison of Percent Turbidity Removal with Logarithm of Particles Removed at Various Alum Doses at the Glenmore Water Treatment Plant

Alum (mg/L)	Date	Percent Turbidity Removed	Log Particles Removed
0	Nov 15/87	34	1.42
5.4	Dec 1/87	80	2.29
7.6	Nov 8/87	88	2.41
10.0	Jan 19/88	66	2.42

CONCLUSIONS

Year-round chemical coagulation was successfully implemented at the City of Calgary's two water treatment plants. Low doses of alum (5 to 10 mg/L) provided enhanced turbidity removal. A general operating range for turbidity of 0.1 to 0.2 NTU was achieved which was considerably better than previously experienced range of 0.3 to 0.8 NTU for the low turbidity and low temperature period. Problems associated with the 0.1 to 0.2 pH unit depression caused by year-round alum dosing were not observed. However, a year-round elevated aluminum concentration averaging 340 ug/L now prevails in finished water. Though elevated and worthy of future plant scale investigations to follow up pilot scale tests of mixed coagulants, these levels are not of immediate concern. They place at the 80th percentile of North American filtered water supplies (20% of utilities have higher values) and the latest regulatory leadership discounts toxicological effects of aluminum in drinking water (17).

The mechanism of enhanced turbidity removal through low alum doses deserves some comment. The latest definitive charge neutralization model, while including dose responses, does not extend to the very low dose case (18,19). The low doses employed are apparently within the solubility amount. Finished water aluminum concentrations did not display a relationship with turbidity breakthrough. Thus, dissolved aluminum was carried through the sedimentation basin to the filters where it exerts a dynamic effect on filtration media enhancing particle retention. This effect may not be unlike enhanced turbidity removal observed when backwash water is dosed with alum (20).

The day to day setting of alum dose based on turbidity removal was not particularly critical. Both pilot scale and plant scale runs yielded similar turbidity in finished water over a range of low doses. However, the higher side of the low dose range caused unstable filter performance episodes such as turbidity spurts with flow changes. It should be noted, though, that turbidity measurements near 0.1 NTU are a rather coarse indicator. Much more precise measurements, such as particle size distribution analyses, would be required for optimizing doses to minimize residual aluminum levels and mixing coagulants at plant scale. Particle size distributions were easily measured and readily visualized. Particle size analysis also provides definitive information on filter performance in contrast to the index nature of turbidity measurements.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the technical work of D. Johnson, C. Leong, J. Mak, P. Mayberry, L. Mielke and E. Schubert. Critical review and operations support was provided by D. Jamieson, R. Prichard, R. Quinn and E. Westerbeek.

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BACK PROBLEMS

Ruth Meltzer
Sports Medicine Clinic

Of all the problems encountered in occupational health, there is no greater than that of the "Problem Back". It affects more people over a longer period of time than any other condition. It is unsurpassed for testing the patience of both doctors, trying to diagnose, manage and treat the problem, and sufferers, trying to recover from it. A complex, costly problem, the impact of back pain on individuals is in the same league as heart disease, cancer and respiratory illness.

Back discomforts have been called the 20th century affiliction. It is estimated that 8 out of 10 people will have a back problem at some time in their lives.

Workers Compensation statistics indicate 3 of every 4 industrial workers will have a significant back problem during their working lives. These injuries are not only restricted to workers involved in heavy, physically demanding work, but also affects people whose jobs require limited activity. The result is usually a serious decline in job efficiency, a downgrading of production due to lost work time and a reduction of the person's quality of life, both on and off the job.

The impact of back problems is underestimated because death is not the end result. Back problems are the leading cause of disability under the age of 45 and the third leading cause of disability over the age of 45. Back and other musculoskeletal problems are increasing at a time when demands on the workplace are decreasing through automation. In the last 10 years in Ontario, the population has increased less than 10% but the number of physiotheraphy and chiropractic treatments has increased by 400%.

Back problems are complex, but clearly traditional treatment of the problem is not working.

Over the years back care programs have been introduced with little change in the problem. In looking at back problems over the last few years the following concerns have been identified:

1. Back problems are recurrent - "once a back problem, always a back problem".

2. The distinction between occupational and non-occupational is arbitrary - today's home accident is tommorrow's work-related injury.

3. Back problems tend to be increasingly severe - today's minor injury is tommorrow's major cost.

4. We cannot just look at the problem - we must look at the person who has the problem.

In working with back patients, it is not just a program of treatment we must deal with, but rather it is a program of MANAGEMENT of the back problem. There are no cures to the problem but only controls. We cannot look just at the pain but we must recognize and realize the importance of painless dysfunction which can lead to pain, weakness and disability.

Treating back pain is not just the problem of the health professional but requires the committment of the individual to deal with the problem to minimize and manage his/her problem.

Ultimately it is you - the individual - who is responsible for your own back. It is up to the health professional to supply the tools in dealing with the problem, but it is the individual who puts the tools to use.

There are many causes of back pain - herniated discs, facet joint snydrome and inflammation. The majority of back pain is the result of mechanical backache caused by musculoskeletal strain.

This form of back pain involves straining muscles, ligaments and other soft tissues. Often this problem recurs and later becomes a chronic source of pain.

Most back pain sufferers will relate their pain to some unusual activity. They complain of lifting the wrong way, twisting, slipping or falling. Safety professionals often categorize the cause of back strain under the heading of "unsafe act or unsafe condition".

However, back strain is better understood by a teeter-totter and characterizing the problem as a "mismatch" between the capability (fitness) of the individual and the demands of the task and environment.

By analyzing back problems this way, the importance of strength and capability is appreciated, as well as unusual activity, trauma or task demands. The importance of poor fitness is largely overlooked as a major contributing factor to the prevalence and recurrence of back problems.

There is no cure for back pain, but then back pain is not a disease which requires a cure. Back pain is a symptom and as a result cannot be cured but rather controlled and, if kept under control, can be minimized.

Over the years many approaches in the form of treatment, education and job design have evolved and yet none have been overly effective.

The data indicates there is no simple solution to the complex problem of back pain in industry. It is quite clear, however, that no single approach by itself will control the problem. An effective control program must be a combination of the three approaches.

1. JOB DESIGN
2. EDUCATION - of the individual, management & unions
3. TRAINING OF THE WORKER - in strength and fitness

Using this multiple approach system, early data is positive and the philosphy of this approach also involves early return to work. Examples of those who have been following this approach are the AMERICAN BILTRITE COMPANY, the POTOMAC ELECTRIC COMPANY, the LOS ANGELES FIRE DEPARTMENT and the JUAN DE FUC HOSPITAL SOCIETY. Success of the program has been positive because of the striking contrast of the nature of these organizations. That is a manufacturer, a utility, a municipality and a hospital, indicating back pain can be controlled regardless of the type of industry.

The success of this type of program is largely dependent on the committment of those involved.

The individual is solely responsible for his/her back. Industry offers many safety devices in the form of hard hats, steel toe shoes, safety glasses, ear plugs and many other items which protect. THERE IS NO PROTECTIVE DEVICE FOR THE BACK.

FERTIGATION OF PROCESS WASTE WATER FROM A NITROGEN FERTILIZER MANUFACTURING PLANT

Gordon Collis
Simplot Canada Ltd.

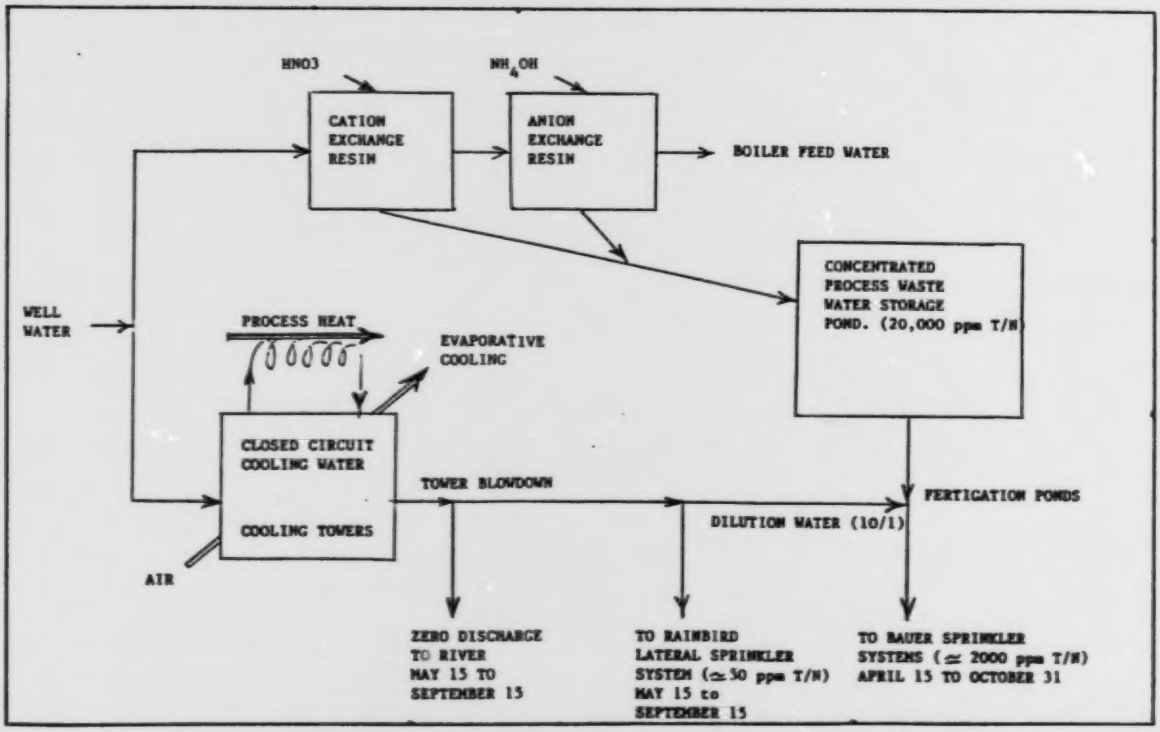
INTRODUCTION

Simplot Canada Ltd., Brandon Manitoba, must dispose of approximately 1000 m^3 of closed circuit cooling tower water per day. This water contains substantially less than the 91 kg per day of ammonia nitrogen and less than the 20 kg per day of phosphate allowed in our effluent permit.

Most nitrogen contaminated water streams are recycled and reused within the plant for nitrogen fertilizer solution production, etc. However, process waste water from demineralizers and plant losses due to contaminated condensate, small leaks, etc. are stored in a concentrated waste pond and are used to fertigate nearby fields each summer. During the summer between April 15th and October 31st, up to 2,273 mg^3/day of cooling tower blowdown water, enriched with concentrated waste pond water as necessary, is used in the single step fertigation of fields belonging to neighboring farmers (95%). These are mainly hay or pasture, with some crop land in the spring and fall.

FLOW SHEET:

FERTIGATION OF PROCESS WASTE WATER ON FARMLAND


HNO3
NH4OH
CATION EXCHANGE RESIN
ANION EXCHANGE RESIN
BOILER FEED WATER
CONCENTRATED PROCESS WASTE WATER STORAGE POND. (20,000 ppm T/N)
WELL WATER
PROCESS HEAT
EVAPORATIVE COOLING
CLOSED CIRCUIT COOLING WATER
COOLING TOWERS
AIR
TOWER BLOWDOWN
DILUTION WATER (10/1)
FERTIGATION PONDS
ZERO DISCHARGE TO RIVER MAY 15 TO SEPTEMBER 15
TO RAINBIRD LATERAL SPRINKLER SYSTEM (≃50 ppm T/N) MAY 15 to SEPTEMBER 15
TO BAUER SPRINKLER SYSTEMS (≃ 2000 ppm T/N) APRIL 15 TO OCTOBER 31

ACREAGE AND APPLICATION HISTORY

YEAR	ACREAGE	MILLION GALLONS	APPLICATION RATE TONNES T/N	LB/ACRE T/N
1984	760	50	59	170
1985	2,217	82	159	158
1986	2,169	48	164	167
1987	1,745	31	120	152
1988*	2,500	50	150	150

*PROJECTED

MAIN FERTIGATION REGULATIONS

1] Zero discharge to river between May 16 and September 14.

2] Fertigation:

a] pH must be between 6.0 and 9.0 pH.
b] 225 Kg/ha (200 lb./acre) MAX N application.
c] NO_3/N in top 120 cm of soil must not exceed 265 Kg/ha (236 lb/acre).
d] 1] Must NOT fertigate land fallowed the previous year or this year.
2] Can fertigate any stubble or active growing crop in the SPRING that will grow a crop this year and also SOME stubble fields after harvest in the FALL provided they are listed on the fine texture soil map.
e] No application after October 31 until April 15.

FERTIGATION MONITORING

- All fields are sampled by Dr. Racz, University of Manitoba.
- Fields fertigated prior to August 31st are sampled September 15 to October 31st.
- Soil samples are assayed for pH, NO^3_2N, P, K, Na, Ca, Mg, conductivity and bulk density.
- Piezimeter wells monitor ground water.

EFFLUENT REGULATIONS

1. Zero discharge to river between May 16 and September 14.

2. a] SHALL NOT DISCHARGE toward river more than 204 Kg/D T/N NH3N, 20 Kg/D P, and 2722 Kg/D SO_4.
b] pH must be between 6.0 to 9.0 AT ANY TIME [AT lift station].
c] Cl residual not more than 1.4 ppm.
d] NO physical evidence of oil or grease in effluent.
e] Analyze sample [a] for T/N, NH3 and NH4+/N, T/P, pH, SO_4, Cl residual*, Na*, Mg**, Ca**, and conductivity, [* to river **to fertigation].

TEETH IN ENVIRONMENTAL LAWS

NEW MANITOBA ACT

	Any Person	Companies	Company Officials
First Offence:			
Fine	$ 5,000	$100,000	$ 5,000
Jail	6 months	-	6 months
Second Offence:			
Fine	$10,000	$200,000	$10,000
Jail	1 year	-	1 year

Plus the judge has the power:

- To suspend the license (which puts the company out of business).
- To order a stop to further offenses (or face contempt of court charges).
- To order a clean up and restore the environment.
- To order restitution (to anyone damaged).
- To fine any profit (resulting from the offence).

Each day and each violation is a separate offence, so no individual or corporation can ignore environmental concerns and stay in business.

IN CONCLUSION

Consultation and cooperation between Dr. Racz, his colleagues at the University of Manitoba, Mr. M. Rutelis of Water Resources, Mr. K. McGill, Director of the Provincial Soil Testing Lab, Mr. C. Moche and his colleagues in the Manitoba Environmental Management Division, the Clean Environment Commission, and the people at Simplot has made it possible to fertigate fertilizer rich process waste water on the land in a way that benefits the Assiniboine River and our farming neighbors without damage to the environment.

INFRASTRUCTURE REHABILITATION INTO THE 1990s

Glenn E. Hood
President
Amalgamated Sewer Services Inc.

Infrastructure is a problem and we all have the problem, some worse than others.

Let us look at some of our real problems in dealing with our infrastructure situation:

1) Funding shortage
2) Political inaction
3) Staff shortage
4) Bureaucratic delay (red tape)
5) apathy at all levels

At a national level, based on 1983 dollars, in a report of Canada's Urban Infrastructure prepared for the Federation of Canadian Municipalities in 1984 we had a $15 billion dollar problem and, translated in 1988 dollars, we are in serious trouble. It is important to note that in the last 15 years public works has been losing ground in budget dollars, dropping from 40% of total budget to less than 30% today. It is little wonder that our Infrastructure problems are of the magnitude that they are.

What are some solutions in the 1990s?

We have to address funding as one prime priority. On this point the author hoped that we might see a plan similar to the E.P.A. problem in the U.S.A. where the budget would be split three ways - 50% Federal, 25% - Provincial - 25% Local. There is no token evidence of any federal money known at this time, but the situation could change based on some recent comments by Ottawa and in particular Mr. Jake Epp.

Ontario, Alberta and Quebec have recently brought out programs of their own on a shared basis with the Municipal government. While the author is not very knowledgeable about the Quebec or Alberta programs, he is familiar with the Ontario Lifelines system of Grants, which vary from 85% for small communities to 50% for larger ones. The program, while not a total infrastructure program, is for water and sewer rehabilitation. It is divided into two needs studies called (SIMS) - "Sewage Inventory Management System" and (WIMS) - "Water Inventory Management Systems". This is a multi-year program involving many millions of dollars to assess and rehabilitate Ontario's water and sewer systems and a remedy of existing water pollution.

Highlights of the Ontario program

PURPOSE

The Needs Study is the corner stone of the Infrastructure Rehabilitation Program. In the Needs Study, deficiencies within existing system are identified, alternatives are considered and the most cost effective solution is recommended. Priorities for an effective rehabilitation program are established and a multi-year rehabilitation program is formulated based upon the findings in the Needs Study. Request for construction grants are then based upon the recommendations in the Needs Study.

The first step in a Needs Study is to establish the extent of the existing system under study. A complete inventory of the sewage collection or water distribution system is, therefore, carried out. This inventory would not only obtain data about the system with respect to location, size, length, pipe material, age, etc. but also with respect to such items as breakage rates for watermains or infiltration/inflow into the sewer systems.

Since there are many municipalities in the province, it stands to reason that the inventory of existing systems should be collected in a consistent format. The data should also be entered on a micro-computer using designated software for ease of analyzing and sharing of information. A computer program known as the "Sewage Inventory Management Systems" (SIMS) has been developed for this purpose. A computer program entitled "Water Inventory Management Systems" (WIMS) should be available by the end of 1988.

The second step is to establish the condition of the existing system through special surveys. The need for these special surveys depends on the conclusions from the inventory survey and/or previous knowledge of the system under study or lack thereof.

Examples of such surveys are leak detection surveys for water distribution systems or close circuit TV camera inspection surveys for sewer systems. Investigations on private property connections is also required.

Another item to be covered in the Needs Study is the evaluation of the existing maintenance program.

Only after the information from surveys, etc. has been collected and analyzed, can the condition of the system be properly evaluated.

Priorities can then be set and a rehabilitation program through cost effective analysis formulated. This program could not only make recommendations for a multi-year rehabilitation work forecast, but would also address such issues as the adequacy of the existing maintenance program and the need for additional by-laws or enforcement of existing by-laws.

Specific terms of reference will have to be developed on an individual basis by the Technical Committee, but should generally cover the following items to maintain consistency in the Needs Study to be carried out for the Infrastructure Rehabilitation Program.

INVENTORY

1) Centralize and review existing "as-built" drawings for relevant data.

2) Prepare complete inventory of the sanitary collection system with respect to location, pipe materials, size, length, age, repair records, maintenance records, and other relevant data, and arrange into format for input into SIMS computer program.

3) Field check for missing information to ensure the completeness and accuracy of the existing data.

4) Input data onto micro-computers using SIMS software (Optional).

5) Prepare drawing showing overall sewage collection systems.

6] Identify sanitary sewer system drainage areas within the municipality.

7] Monitor sewage flows for each drainage area within the municipality to establish actual dry weather and wet weather flows.

8] Calculate design flows for each drainage area.

9] Summarize data from the actual flow monitoring program and compare to calculated design flows for the various drainage areas.

10] Establish ground water level variations for the various drainage areas.

11] Obtain and review repair records and identify problem areas within the municipality.

12] Identify and concentrate more detailed analysis in the drainage areas with the worst extraneous flows.

TESTS ON THE SYSTEM

1] Conduct a visual survey of the sewer system (interior) to determine the physical condition of the sewers, appurtenances and service connections (private and public side).

2] Conduct a house to house survey to determine individual sources of flow such as roof leaders and sump pumps.

3] Conduct smoke testing to detect possible sources of inflow, such as roof leaders and catchbasins.

4] Conduct, as necessary, a TV inspection survey of suspect lengths of sanitary sewer including service connections for infiltration and structural deterioration.

EVALUATE DATA

1] Evaluate all survey data.

2] Enter data on Sewer Inventory Management System (SIMS) computer program (Optional).

3] Analyze repair records and determine causes for high repair items and evaluate alternative to correct the causes.

4] Determine the structural integrity of the sanitary collection system and its appurtenances.

5] Identify specific rehabilitation needs of the sanitary sewer system and evaluate alternative solutions.

6] Determine and quantify sources of extraneous flows and evaluate alternative to reducing extraneous flows on public and private side.

7] Review and evaluate municipality's existing maintenance program, and determine the need for improvement.

8) Review the existing by-laws, their enforcement and determine the need for improvements.

RECOMMENDATIONS

1) Identify cost for the various alternatives.

2) Evaluate the various alternatives for corrective work based on all study results and develop the most cost-effective solution.

3) Set priorities and develop a multi-year rehabilitation program to correct the deficiencies within the sanitary collection system along with estimated costs of the program.

4) Prepare and submit a written report in "draft" form the comment by Technical Committee.

5) Review "Draft" report with Technical Committee.

6) Revise report based upon Technical Committee comments and issue final report.

The Water Needs Study is very similar to the Sewer Study. The tools have not changed too much over the years in respect to the Needs Study as our I & I study is regarded as a very sophisticated C.C.T.V. program along with a thorough cleaning program. I might point out that there are only two firms of which the author is aware that are equipped to do a thorough I & I study in Western Canada.

Sliplining, Grouting and Insituform are still the popular Rehabilitation tools being widely used and the balance is by replacement. Another area of concern will be rehabilitation of all manholes and this can be a source of a lot of infiltration and exfiltration problems. Service line infiltration is another serious area, and sealing these can be very difficult with a very low success rate, but a lot of research is being done on this problem.

Infiltration is, in the author's belief, treated far too lightly by many Public Works people-maybe as a necessary evil. Depending on the quantity, pumping all this water may be costing a fortune and, with everyone on the budget wagon, here is a place to cut some dollars for use somewhere else.

Exfiltration is a serious matter to the environment in continuance of waterway wells, etc. Using 80 gallons per person per day, the author recalls a that about five years ago a small community in North West Ontario was putting an excess of 250,000 gallons per day over the lift. By sealing 36 manholes, that excess was cut by about 150,000 gallons per day. In the future, Demand Orders from Provincial and Environmental Department will in no uncertain terms tell Municipalities to clean up their act. It is happening in Ontario right now. The author's company is involved in one of these situations at this time with a small community in North West Ontario which has an excess factor of about four to one. The Ministry of Environment has ordered a clean up on the sewage system along, including joint sealing and manhole sealing which will run into hundreds of thousands of dollars. This project is on a Lifeline Grant program.

In conclusion, the author hopes that this paper has assisted in realizing the magnitude of the infrastructure problem.

RED RIVER REGIONAL WATER SUPPLY SYSTEM
CONCEPT ...TO...REALITY

Dick Menon, M.Eng., P.Eng.
Chief Engineer
Manitoba Water Services Board

GENERAL

Regional systems, while new to Manitoba, have been in existence for many years south of the border. In Manitoba, the first truly Regional water supply system (Red River) was put in operation in late 1986. A second system, in the Rural Municipality of Macdonald, will be in operation in early 1989. The Westlake Regional system in the Municipality of Westbourne is presently in planning stages. Regional systems offer a cost effective water supply to rural residents and are the systems of the future.

CONCEPT

The Red River Regional Water Supply system is located in the south central area of the Province of Manitoba and is commonly referred to as the Pembina Triangle. The area extends about 100 km southwest of Winnipeg, The groundwater in this area is saline and there are no streams able to be developed in a relatively flat terrain (Figure 1).

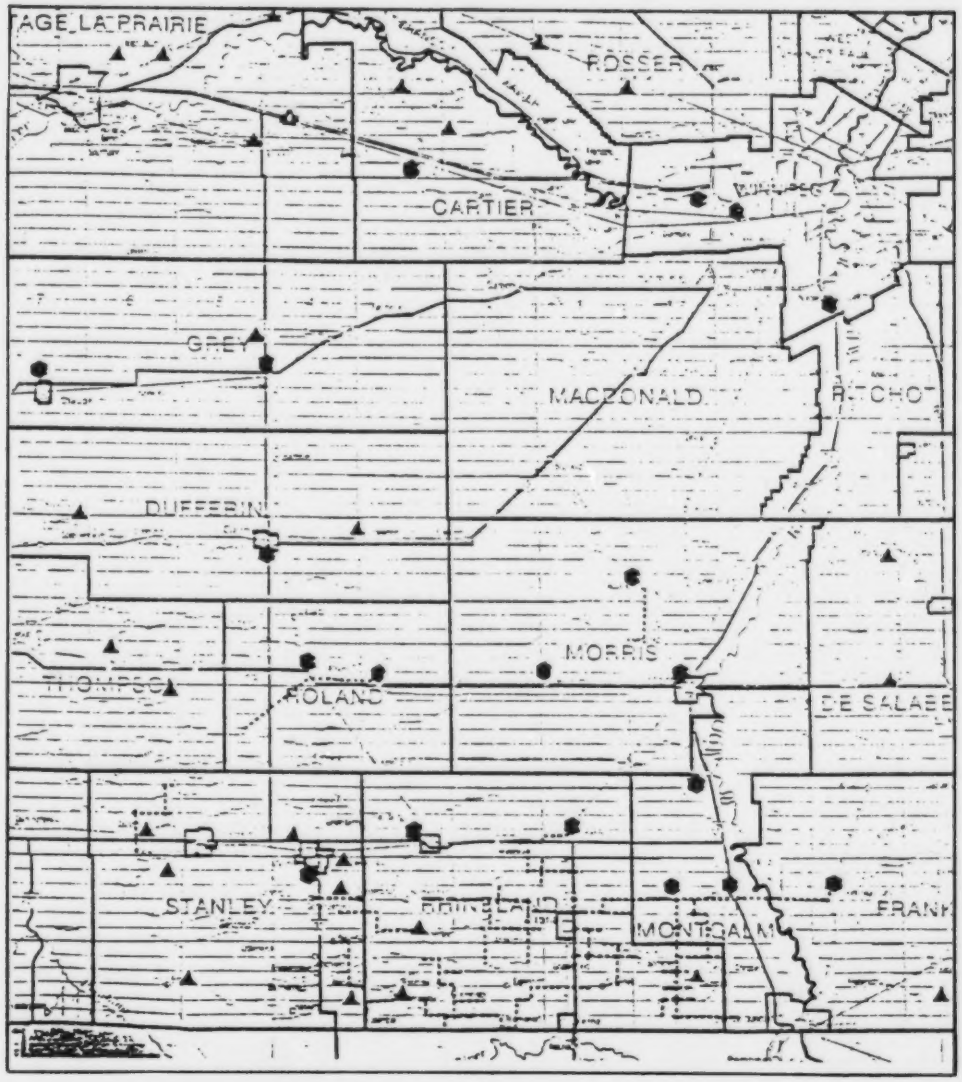
The cost of public water supplies has been a disadvantage to the long term development of this area, which is considered to be the most productive agricultural area in the Province of Manitoba.

In the late 1950's, the Manitoba Government established an agency, today known as the Manitoba Water Services Board (or MWSB) with the responsibility of providing technical and financial assistance toward the establishment of rural water supply infrastructures. MWSB devised a plan which would have provided water supplies from several plants to dozens of towns, villages and many rural residents, a truly Regional concept. Unfortunately, economics and politics on the local level resulted in a fragmented implementation of this concept. Communities located near existing developable supplies proceeded on their own to build water supply systems for their local needs.

Investigations, conducted in the '50s by MWSB, indicated that the most attractive and economic scheme for providing the Town of Altona and the Village of Gretna with potable water immediately would be one which involves the construction of a pipeline from the Neche Water Treatment Plant, located in Neche, North Dakota, to Altona via Gretna. Future options for increasing the water supply involved the construction of a reservoir on the Roseau River, east of Dominion City. Most smaller communities were left "dry" and their residents, as well as the farmers in the area, continued to haul water from sources many kilometers away.

The City of Neche, N.D., draws water from the Pembina River (Fig 1). In June 1980 the MWSB signed a 10 year agreement with the City of Neche for providing potable water to the Altona area. In 1981 a 200mm (8") diameter pipeline was built between Neche and Altona with reservoirs at Gretna and Altona. The original agreement with Neche was renewed in 1970 for a further 10 years. This permitted the construction in 1976 of a 100 mm (4") diameter branch pipeline to serve the Rhineland hamlets of Gnadenfeld, New Bergthal and Sommerfeld. This line is commonly referred to as the GNS line, taking the first initials from the names of the three hamlets.

FIGURE 1
Altona and Area



Growth and Options

The growth of the Town of Altona, with its commercial and industrial bases, provided the seed for the return to the original concept of a Regional system. The Town's water demand exceeded the supply capacity of the Neche plant in the late '70s. The output of the Neche plant is 2.1 MLPD (24 L/s) of which about 15% or 0.35 MLPD is consumed in North Dakota. The peak 1980 hourly demand in Altona area was 28 L/s. This was cushioned only by the 0.31 ML water tower at Gretna and the 1.45 ML in ground reservoir at Altona.

Studies were undertaken by the MWSB in the late '70s, to determine the feasibility of supplementing supplies to the Altona area. Four options were looked at in detail, namely:

1) the Pembina River
2) the Red River
3) the Roseau River
4) the Buffalo Channel, northwest of Altona

The firm supply yield of the Pembina River at Neche was questionable, in terms of the long term demands on the Canadian side. In addition, the plant at Neche on the Pembina River had reached its full capacity and was found to be inadequate for expansion without the construction of the Pembellier Dam in North Dakota. As construction of the dam was extremely uncertain, no further study was made on the possibility of expanding the plant at Neche.

The Red River proper originates near the southwest corner of the State of North Dakota. The bulk of the flow originates from a watershed located in the U.S. The study showed that there were a number of potential sites on the Red River which could be developed for a water source without the requirements of an in-channel control structure to create an impoundment. However, this option required the construction of a 25K pipeline from the Red River to Altona.

A dam on the Roseau River at Dominion City was found to be too expensive due to the in-channel structure and the 34K pipeline that would have been necessary to convey water to Altona. Therefore, this option was not considered further.

The last option considered was the development of the Buffalo Lake Channel. The report indicated that the construction of an in-channel control structure, pumping station, and a dugout fed by the Buffalo Lake Channel would provide a firm supply to adequately service the needs of the Altona area, either as a sole source of supply or as a supplementary source to Neche.

Selection

In 1981, the management group for the Canada-Manitoba Interim Subsidiary Agreement in water development approved a proposal for inclusion of a study for water supply to the Altona area. Although the above noted four options plus groundwater were dealt with, due to the renewed interest in the Pembellier Dam on the Pembina River and the studies on the Assiniboine South-Hespeler Canal, it was decided to look at shorter term solutions to water shortage in the Altona area, while a decision is reached on the two larger projects. The study therefore considered the two most feasible sources, namely the Pembina River and the Buffalo Channel.

Local government officials indicated a preference for a reservoir on the Buffalo Channel and a new treatment plant at Altona to supplement the output from the Neche plant, although this option was much more expensive than the Pembina River options. The Buffalo Channel option could be used with the proposed Assiniboine South-Hespler Canal to supply water to the area after 1992, as the Canal could bring water to Buffalo Channel to supplement runoff from the drainage basin.

In 1983, the Manitoba Water Services Board commissioned an Engineering Study to provide short term and long term water requirements of the Altona area. At the same time, PFRA performed further hydrologic analyses to determine the storage needs on Buffalo Channel to drought proof the Altona water supply. During these analyses, PFRA discovered some discrepancies in the evaporation data and the estimated flows in the Buffalo Channel used for the yield calculations. Therefore all the hydrologic data was reviewed and the yield calculations for a reservoir on the Buffalo Channel repeated.

The new calculations showed that the proposed dam could not store enough water to supply Altona's short term (1992) demands without the construction of an off-channel dugout storage. When the revised cost estimates were compared, it was found that the cost supplying water with a 22 km pipeline from the Red River at Letellier would be far less expensive than the updated Buffalo Channel option.

The quality of the Red River had been a concern in previous studies. Spills from a sugar beet plant and releases of saline groundwater appeared to be the main water quality concern for the Red River. With the exception of short periods, when the water quality was impacted by spills, or flows were low, it appeared that the Red River had been a good municipal source since 1961.

PFRA investigated methods of supplying water from the Red River, assumed an intake and pumping station on the Red River near Letellier, whereby water would be pumped through a pipeline into the Oxbow of the Aux Marais River from which the existing water treatment at Letellier obtains water. This would provide protection against "slugs" of poor quality water which periodically come downstream from North Dakota. It was decided that the treatment plant would be built at Letellier rather than at Altona, since other communities in the region could also be serviced with treated water.

Red River Regional Water Supply System

Having selected the Red River as the source of water supply for the Altona area in 1984, the MWSB retained the services of A.J. Postker and Associates Ltd. to carry out a feasibility study for the water treatment plant at Letellier. MWSB staff undertook a study to provide treated water to all the rural residents in the area.

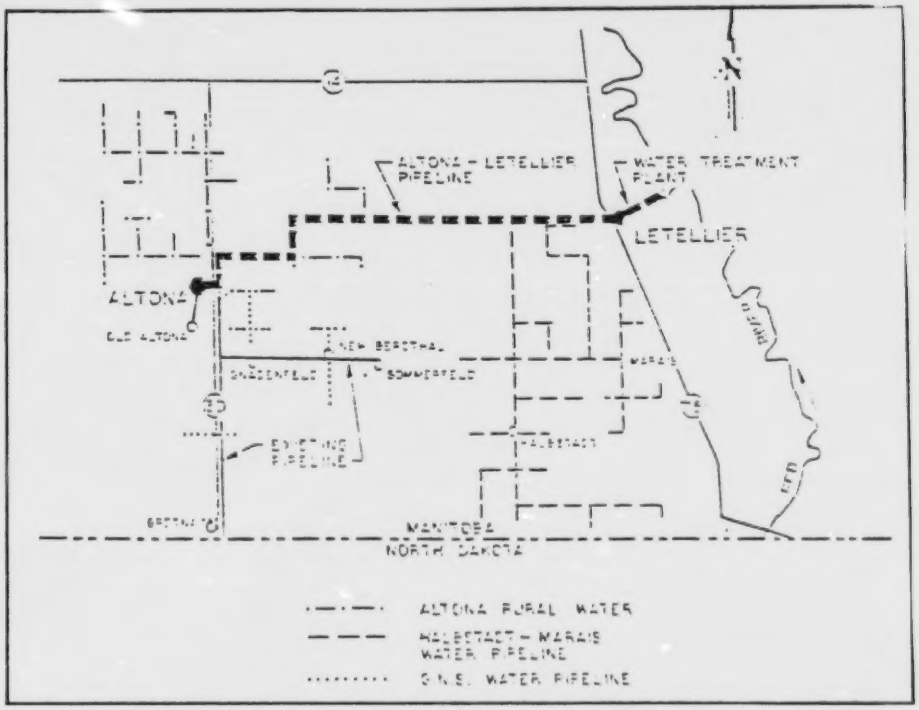
PFRA, under the joint Canada-Manitoba Agreement, constructed a 22K, 300 mm pipeline between Letellier and Altona as well as a river intake, pumping station and transfer pipeline, from the Red River to the Marais Oxbow treatment plant. The design work for the plant and the rural pipelines started in 1985 and construction was completed in late 1986.

The total cost of the system as constructed in 1986 cost $5,620,000. The costs were shared as follows (Figure 2).

Federal Government (PFRA)		$ 1,520,000
Provincial Government (MWSB)		2,180,000
Local groups	(capital)	920,000
	(through water rates)	1,000,000

FIGURE 2

Red River Regional Water Supply System



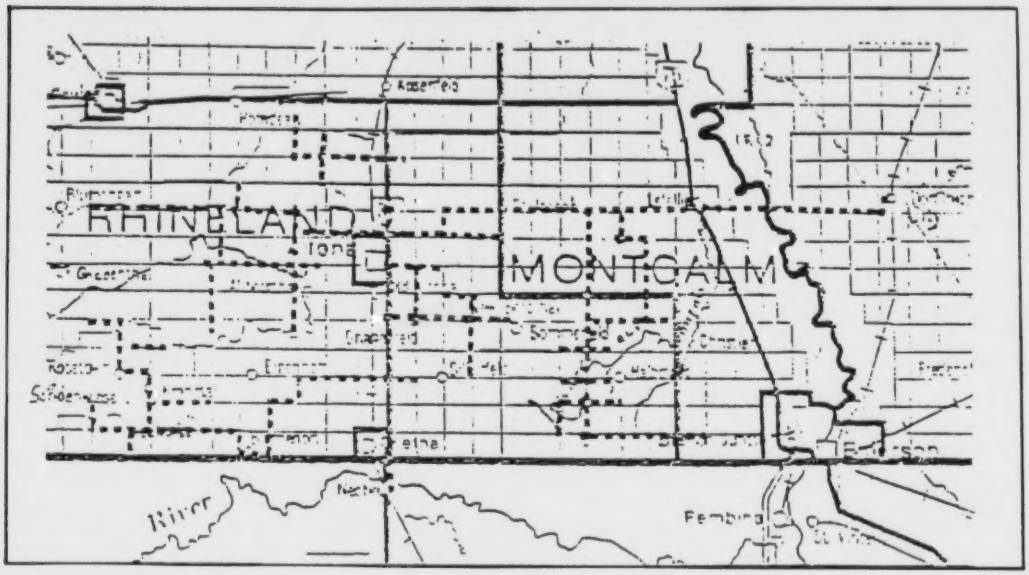
Future Expansion

The plant at Letellier was sized (32 l/s) to meet the 1995 need of the Towns of Altona, Gretna, Dominion City, Roseau River Reserve, Letellier and the farm households in the Municipalities of Rhineland and Montcalm. Future proposals include servicing St. Jean Baptiste and Emerson, although the line to Emerson is not viable at this time. Timing of the future expansion will depend on the ability to renew the present agreement with the City of Neche.

The present agreement with Neche, signed in 1981, terminates in 1995. The City could, however, terminate the agreement as early as 1991, provided they give the Board a five year notice. The present agreement stipulates that the Board must purchase a minimum amount of water before supplementing with other sources.

The primary objective of this project was to serve the Town of Altona. Conversely, without Altona, a truly Regional project of this magnitude may not have been possible. The system presently serves over 5000 people. Presently there are over 150 miles of agricultural pipelines serving some 300 to 400 rural homes. Most of the rural water usage is designed and restricted on the basis of a 2 gpm per hookup. All rural groups are pressurized from smaller group reservoirs which have been designed to allow truck filling for domestic and/or spraying purposes. (Figure 3)

FIGURE 3
Red River Regional Water Supply System 1988



Future Developments

The advantages to Regional systems are obvious. Economies of scale provides cost saving in both Capital as well as the O & M costs (cost of producing water). The most important advantage is really to the hundreds of rural homes who now do not have to haul water all year. Development of the system has been a lesson in cooperation between various groups to work toward a common goal/good.

The success of the Red River Regional Water System has encouraged the Municipality of Macdonald to proceed with such a regional system to serve not only the residents of the Municipality, but some residents in the Municipalities of Cartier, Grey and Morris. Presently the MWSB is constructing Phase I of a Regional system in Sanford. (Figure 4)

A third regional water system is presently in the planning stage in the water short area of the Westlake area around the Town of Gladstone (Figure 5).

FIGURE 4

Macdonald Regional Water Supply System

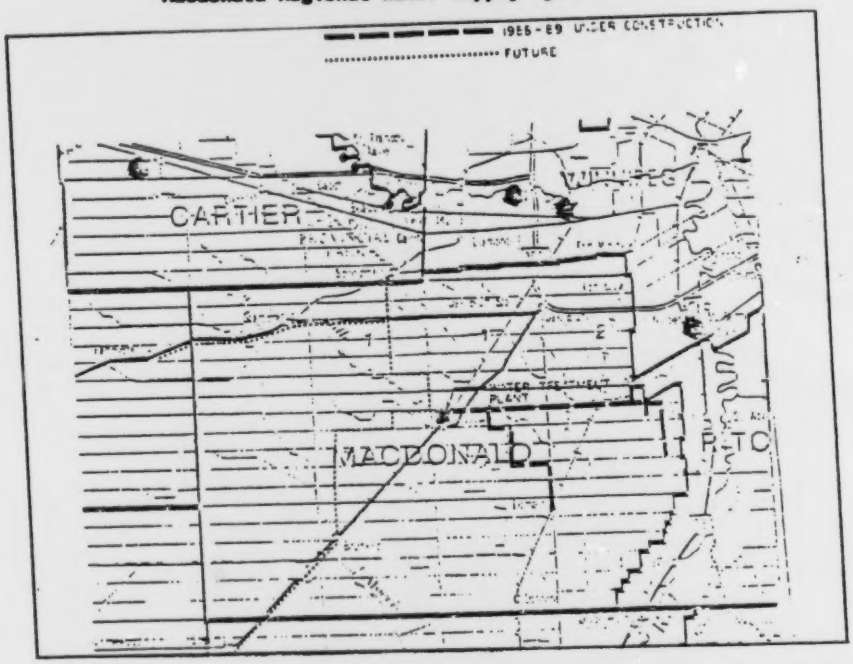
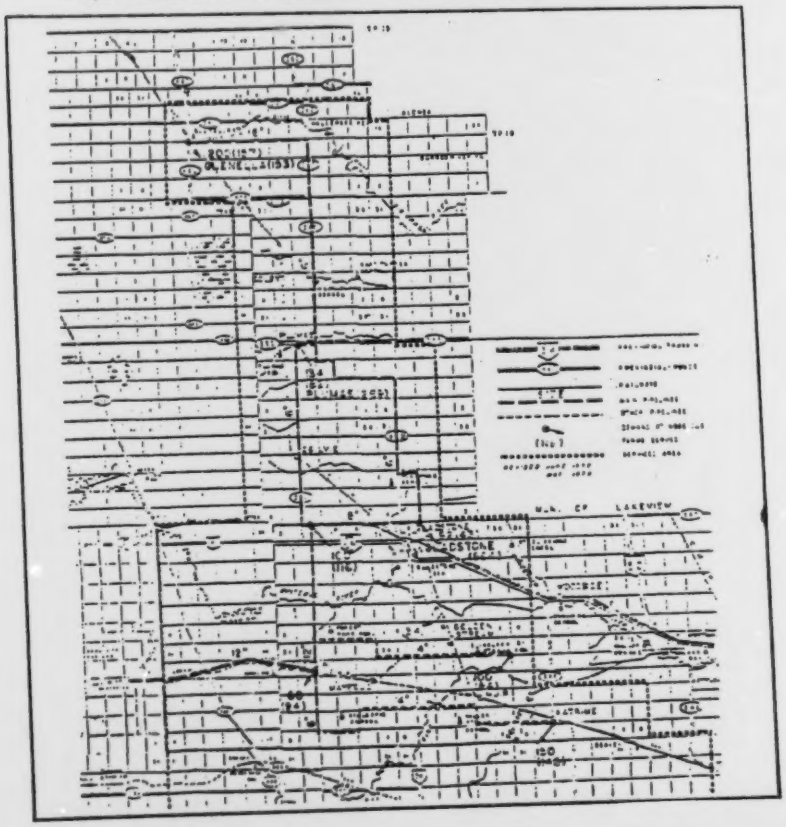


FIGURE 5

Proposed Westlake Regional Water Supply System



A NOVEL APPLICATION OF DIRECT FILTRATION AT THE LIMESTONE GENERATING STATION

John W. Markowsky
Manitoba Hydro

David L. Woytowich
University of Manitoba

INTRODUCTION

In recent years, direct filtration has received renewed interest as a viable alternative to conventional sedimentation-filtration systems when source waters are low in turbidity and color. Direct filtration has been defined as a treatment system in which filtration is not preceded by in-plant sedimentation of flocculated water (1). Direct filtration is frequently preferred over conventional treatment processes because of savings in capital, operational and maintenance costs. The lower capital costs result from fewer process steps (e.g. sedimentation units) and a reduction in space requirements. In the past, most direct filtration plants were constructed for industrial use.

The direct filtration process differs from the conventional sedimentation-filtration system in that total solids, both natural and added, must be stored in the filter. In conventional treatment, attempts are made to produce a settleable floc and remove the floc in the settling basin. In the latter, the filter is used primarily as a polishing process. In direct filtration a non-filterable floc, rather than a settleable floc, is the objective, and all solids removed from the water are stored within the filter bed.

During the spring of 1985, the firm of A.J. Postker & Associates submitted a proposal to Manitoba Hydro identifying conceptual solutions for the water treatment problems associated with the raw water supply at Limestone. Preliminary engineering studies indicated that a direct high rate deep bed (herein referred to as HRDB) filtration, may be the most cost effective alternative for potable water treatment at the site.

BACKGROUND

The Limestone Generating Station on the Nelson River was initiated in the early 1970's. The proposed construction activity resulted in a substantial influx of workers, some with their families. Manitoba Hydro was required to provide water and sewer services to accommodate the requirements of the residential and work areas related to the project. As shown in Figure 1, these were the Sundance residential community, the main camp, the Limestone Generating Station (LGS) work area and the Henday Converter Station.

The source water for the project is the Nelson River. The average levels of turbidity, color, iron and manganese of the raw water shown in Table 1, exceeded the maximum acceptable levels set forth in the Canadian Drinking Water Guidelines.

The quality of the raw water source and the quality objectives for the filtered water form the basis of selecting a treatment process. The primary objective in the design of the water treatment plant at Limestone was to reduce turbidity to acceptable levels at minimum cost.

FIGURE 1

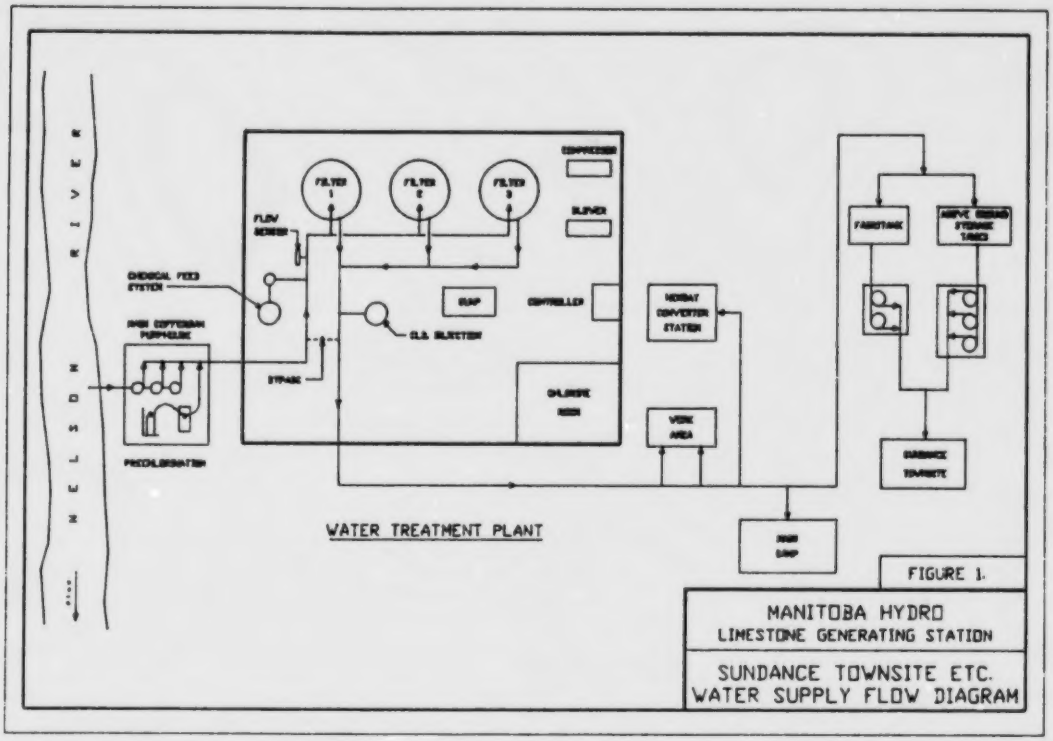


TABLE 1
Raw Water Quality – Nelson River at Limestone

Water Quality Parameters	Average	Max Recorded	Max Acceptable	Objective (Less Than)
Turbidity (NTU)	15.20	70.00	05.00	<01.00
Apparent color (CU)	32.00	50.00	15.00	<15.00
Iron (mg/l)	00.58	07.40*	00.30	<00.05
Manganese (mg/l)	00.06	00.68*	00.05	<00.01
pH (pH units)	07.80	08.10	–	–

* These values were considered to be aberrations and were excluded from average value calculations.

Other variables considered in the process design were temperature, hydraulics, and the effect of pre-chlorination. For example, a significant operating design variable affecting the hydraulic performance of the HRDB filters was flow variation resulting from a fluctuating population at the Limestone Main Camp (see Figure 2). The average daily water demand (see Figure 3) is estimated to be 950,000 liters (209,000 ig).

FIGURE 2
Limestone Project

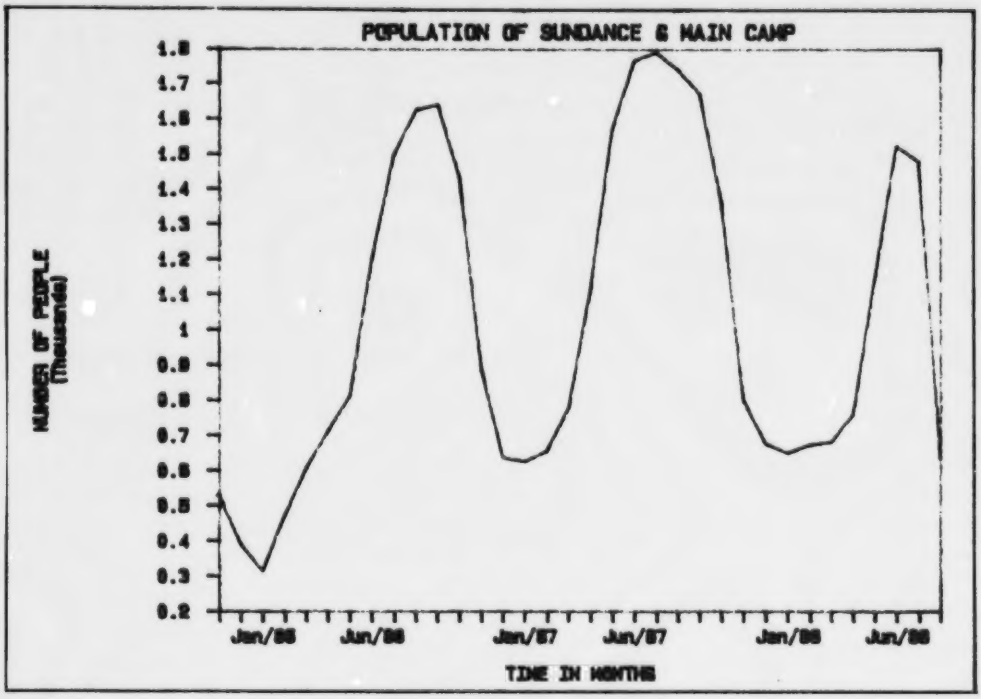
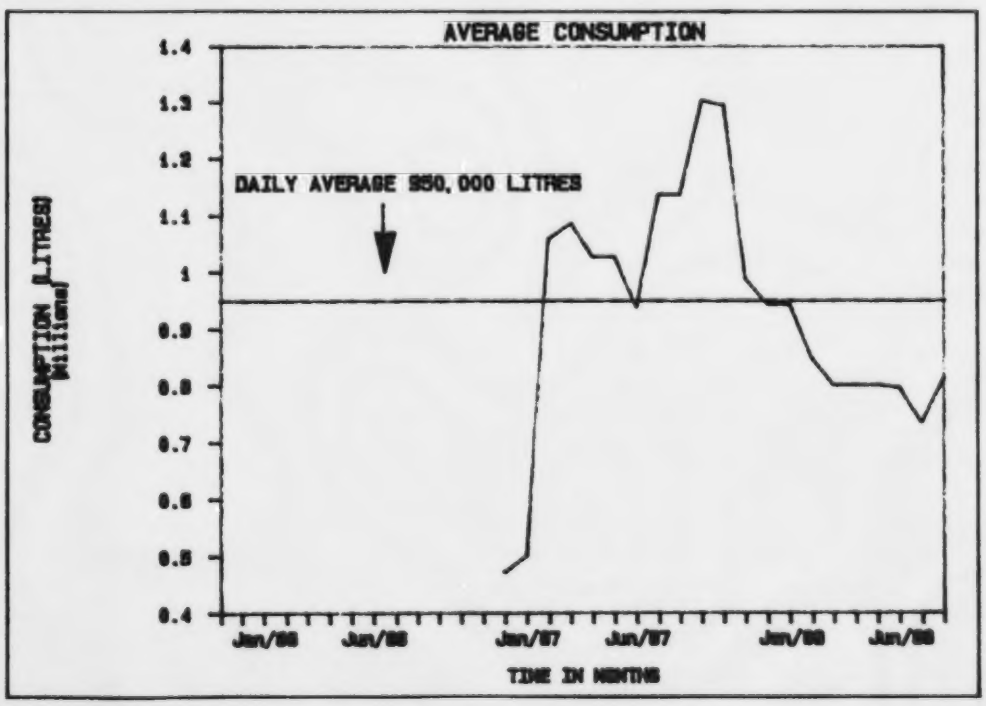


FIGURE 3
Limestone Water Treatment Plant



Project Development

The development of the project consisted of three phases: a feasibility study consisting of laboratory bench scale testing, a pilot plant study conducted at the Limestone Site and the final plant design, construction and commissioning.

Feasibility Study

The method used to determine the feasibility of HRDB filtration was bench scale testing. The bench scale tests were conducted on a trial and error basis to determine the best coagulant, the optimum dosage, sequence of treatment and temperature effects.

In general, the feasibility of direct filtration for a water supply is dependent on low dosage treatment. Studies indicate that if the coagulant dose is less than 6 to 7 mg/l the water is an excellent candidate for direct filtration. If the dosage is more than 15 mg/l it is a doubtful candidate (2).

Preliminary testing for raw and prechlorinated water samples was conducted using two coagulants: alum and a cationic polymer. Various chemical dosages were applied, followed by flash mixing, flocculations and filtration through laboratory filter paper (1). Preliminary results indicated that the best combinations of alum and polymer to meet maximum acceptable turbidity levels were dosage concentrations of 15.0 and 0.5 mg/l respectively. Alum was excluded from further studies due to the high dosage requirement and the possibility of blinding or plugging in a full scale HRDB filter. The effectiveness of alum in removing apparent color without flocculation was not substantiated. The results, however, did suggest that low dosage treatment was feasible using cationic polymer, Nalcolyte 8103 [Alchem Inc.], as the primary coagulant. Polymer dosages in the range of 1.0 to 2.0 mg/l were effective in reducing turbidity levels from 22 to 5 NTU without flocculation.

Additional bench scale tests were conducted to stimulate an HRDB filter in the laboratory. Prechlorinated raw water treated with NACOLYTE 8103 was filtered through a small diameter, Ecodyne monomedia sand [Ecodyne Media - Varivoid Filter System - Graver Water Division] column at an overflow rate of 3.2 lps/m^2 (3.9 igpm/ft^2). The tests were conducted at room temperature (approximately 20°C) and cold conditions (7°C).

The results of the laboratory prototype indicate that acceptable turbidity levels were achieved at room temperature for polymer dosages in the range of 1.0 to 2.0 mg/l. In addition, apparent color was reduced by approximately forty percent (ie: from 40 to 25 CU). The HRDB monomedia sand filter, however, plugged at a polymer dosage of 2.0 mg/l for the cold temperature condition.

It was concluded from this observation that there may be potential operating problems with an HRDB filter for cold temperatures. Consequently it was decided that further pilot plant studies were required at the Limestone Site during the winter months.

Pilot Plant Study

Manitoba Hydro accepted a proposal submitted by Ecodyne to evaluate the on site performance of an HRDB filtration system utilizing a monomedia sand filter for cold temperature conditions. The pilot plant would be operated during the winter months for various polymer dosages and overflow rates.

A.J. Postker & Associates were retained to oversee the operation, evaluate the test data and to develop reliable design parameters for a full scale water treatment facility if the pilot plant was successful. The pilot filter system was set up by Ecodyne personnel in the wash bay of the Limestone maintenance building in January 1986. The 500 mm (20 inch) diameter filter, 2.7 meters (9 feet) in length, was connected to a pressurized 50 mm (2 inch) diameter prechlorinated water intake line. The HRDB filter was filled with 1.5 meters (5 feet) of Ecodyne sand media (1.2 to 1.5 mm in diameter). The underdrain consisted of a patented plastic strainer system which eliminated the need for a series of graded gravel support layers.

Initially the filter was given a thorough air/water backwash to remove dust and small particles from the media. The chemical feed was set to obtain an estimated 2 mg/l of polymer feed into the raw water. Flow control was exercised manually by adjusting the gate valve on the inlet water supply line. During operation the objective was to determine the flow rate and chemical feed rate required to provide an acceptable quality of water.

A.J. Postker & Associates concluded that the HRDB monomedia filter, conditioned with cationic polymer Nalcolyte (8103), could provide acceptable potable water for a range of operating conditions. A minimum of three filters with a total filter area of 7 m^2 (70 ft^2) was recommended to come on stream to meet actual water demand. The pilot plant study indicated that the units could be designed for overflow rates in the range of 2.7 lps/m^2 (3.3 igpm/ft^2) to 6.1 lps/m^2 (7.5 igpm/ft^2). The average polymer dosage for the range of overflow rates investigated was 2 mg/l. Since the flow will vary, it was recommended that the polymer feed rate be automatically adjusted in proportion to the flow through the filters.

It was also observed during the test program that immediately following the air/water backwash the water quality was less than acceptable. Consequently, it was recommended that a rinse-to-waste feature be incorporated into the design of a full-scale plant followed with post chlorination.

Manitoba Hydro decided to proceed with the design of a full scale HRDB filtration plant based on the success of the pilot plant study findings. The final design and specifications were prepared by Manitoba Hydro and submitted for tendering purposes.

Water Conditioning of Canada (WCC) was successful in quoting on the supply of the treatment systems. WCC proposed using a mono media filter to meet the water quality and design criteria specified for the project.

Final Plant Design and Operation

The main components of the water treatment plant (shown in Figure 1) consisted of three automatic mono media sand filters controlled by a General Electric process controller (Manco Control Systems Inc.). Flow data is programmed into the controller to regulate the operation of the filters. Each filter is operated at a maximum overflow rate of 8.5 lps/m^2 (8.0 igpm/ft^2). When the flow rate to the plant exceeds 17 lps (224 igpm) the second filter will automatically come on stream and provide filtered water until the overflow rate in the second filter reaches 8.5 lps/m^2. Subsequently, the third filter will operate up to the maximum design flow of 57 lps (752 igpm). As the flow decreases, the filters will automatically shut off in the reverse order. Small oscillations in the flow rate, over short periods of time, may interfere with the operation of the filters. Consequently, the flows (programmed in the controller) which initiate filter operation are greater than the flows which are programmed to shut off the filters.

This mode of operation ensures uniform solids loading to the filter. In addition the controller is programmed to accept proportional flow meter output readings and automatically feed the Nalcolyte 8103 polymer in proportion to the filter overflow rates. A summary of design details for the mono media filter is shown in Table 2.

TABLE 2
Mono Media Filter Design Details

Tank Details	Diameter = 1.8 M (6 ft) Height = 4.5 M (15 ft) Area = 2.8 m^2 (27.5 ft^2)
Distribution Systems	False bottom 3/4" N.P.T. at 8" on centre 61 nozzles required each tank
Air Wash - Head Lateral	2" PVC Header complete with .001 slots
Support Bed in Each Tank	11 cu.ft: 1/2 x 1/4 washed quartz 11 cu.ft: 1/4 x 1/8 washed quartz 11 cu.ft: 1/8 x 1/16 washed quartz
Filter Media	166 cu.ft.: 1.2 x 1.5 mm washed gravel Depth = 1.5 m (5 ft.)
Note:	Media is placed in tanks in order of size from the bottom.

In normal service operation the flows are such that the controller will operate between two filters for treatment. The controllers memory keeps track of each filter's actual operating time. The backwash cycle is activated following twelve hours of filter service. The flow is reversed through the filter during the backwash cycle. Untreated water flows upwards through the filter at a rate of 18 lps (238 igpm). The backwash cycle contains an automatic air scour assist which pumps air into the tank at 43 lps (90 cfm) through an air wash grid. The backwash is programmed to operate for 15 minutes.

The rinse cycle (downward flow mode) follows immediately after backwash. The rinse cycle continues for 4 minutes, which allows for one tank volume of unfiltered water to pass through the filter system.

Construction and Commissioning

The entire design process, construction and commissioning of the plant, took place over a nine month period. The as built system is shown in Table 3.

On December 10, 1986 the filters were placed into service. The commissioning team proceeded with evaluating the performance of various components of the plant. Problems were encountered with the flow meter, consequently the polymer feed rate was set on the basis of projected daily water consumption. Within 24 hours the average raw water turbidity was reduced from 43 to 1.5 NTU.

TABLE 3
Limestone Water Treatment Plant
as Built Schedule

ACTIVITIES	1986 M	J	J	A	S	O	N	D	1987 J	F	M
Design & tender (MH)	├	─	─	─	┤						
Procurement (MH)		├	─	─	─	─	─	┤			
Site Work and Slab (BK)				├	─	─	┤				
Pre-Engineered Bldg.Erection(AS)						├	─	─	─	┤	
Mech/Elec. Installation (S)							├	─	─	─	┤
Commissioning (MH, WCC, AJP)									├	─	─

(MH) - Manitoba Hydro, (BK) - Bechtel-Kumagai, (AS) - Argyle Steel,
(WCC) - Water Conditioning of Canada, (AJP) - A.J. Poetker & Associates,
(S) - State Contractors Inc.

The filters were initially tested at a maximum overflow rate of 10 lps/m^2 (12 igpm/ft^2). This rate was approximately 50% greater than the design overflow rate. The pressure drop across the filter was insignificant even though the filter had been operating without a backwash for over 14 hours. The filtered water turbidity increased to 2 NTU, still within the acceptable limit.

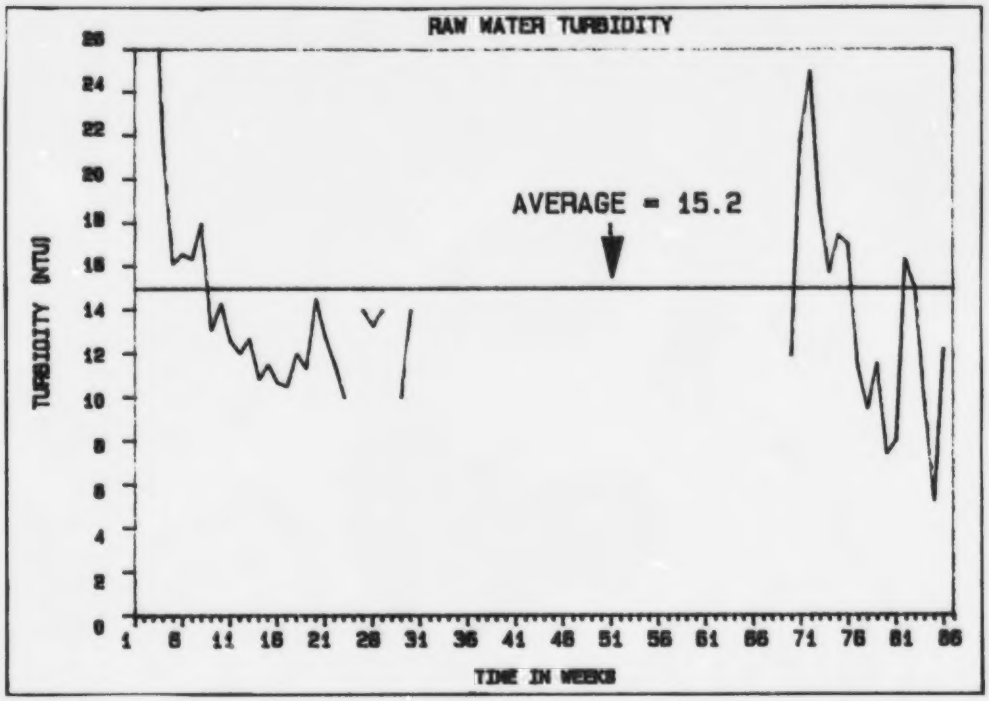
The final test was to operate the three filters simultaneously. The objective was to evaluate the performance of the filters at low flows. It was anticipated that the low flows would accelerate blinding or plugging. The turbidity of the filtrate was recorded at less than 1 NTU after 16 hours of such operation. It was concluded that the filters could be successfully operated without plugging problems for all levels of fluctuating flows.

Two main problems were encountered during commissioning of the plant. The output from the flow meter to the controller was inaccurate. The plant had to operate in the manual mode until the problem was corrected. Secondly, there were serious mechanical failures associated with the separation of several distribution nozzles and the air/backwash header inside the filters. This resulted in the filter being taken out of service. A large number of mud balls were observed while the filter media was being removed. These had developed in less than one month of operation. It was concluded that the lack of air scour, during the backwash cycle, was responsible for their formation.

Plant Evaluation

The plant has now been in operation for two years. The raw water turbidity during this period varied from 4 to 70.0 NTU. The high turbidities normally occurred during the spring or periods of high river flow. The average turbidity shown in Figure 4 was determined to be 15.2 NTU. The temperature of the raw water at the plant also ranged from 0°C to 19°C. In addition to extreme raw water quality variations, the plant evaluation was conducted during extreme fluctuations in water demand.

FIGURE 4
Limestone Water Treatment Plant



As shown in Figure 5, the plant was effective in reducing turbidity levels from an average value of 15.2 to 2.4 NTU (ie. 84% removal efficiency). A histogram of filtered water turbidity data is shown in Figure 6. The largest number of recorded daily values occurred between the range of 1 and 2 NTU. The plant was capable (ie. 94% of the time) of producing a filtered water that met or was below the maximum acceptable level of 5 NTU. This was achieved at a maximum overflow rate of 6.5 lps/m^2. In the future, if objective values of less than 1 NTu are required, additional filters, with a maximum overflow rate of 3.5 lps/m^2 (4.3 igpm/ft^2) are recommended. This recommendation is based on the earlier results of the pilot plant study.

It was observed that apparent color was removed by approximately 52 percent during the treatment. The evaluation, however, was only conducted during a three month period and additional monitoring is required to confirm the significance of the results. The filtered water did meet the average maximum acceptable values of 15 CU (see Figure 7).

The average polymer feed rate during the evaluation period was determined to be 1.93 mg/l. The high polymer feed rate at the beginning of the time period (see Figure 8) is associated with start up.

FIGURE 5

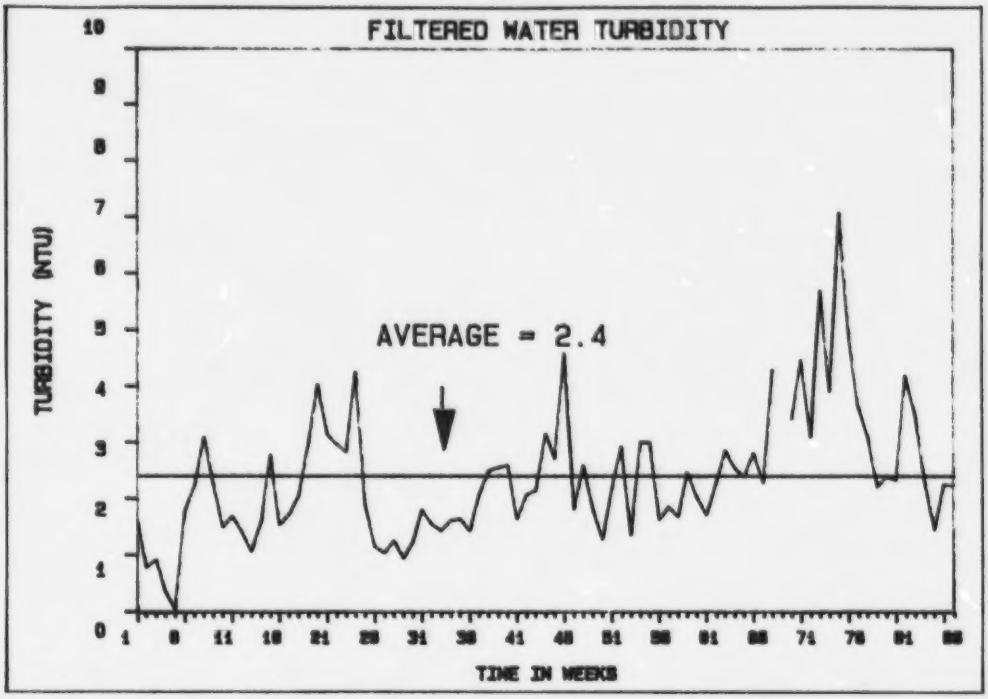


FIGURE 6
Limestone Water Treatment Plant

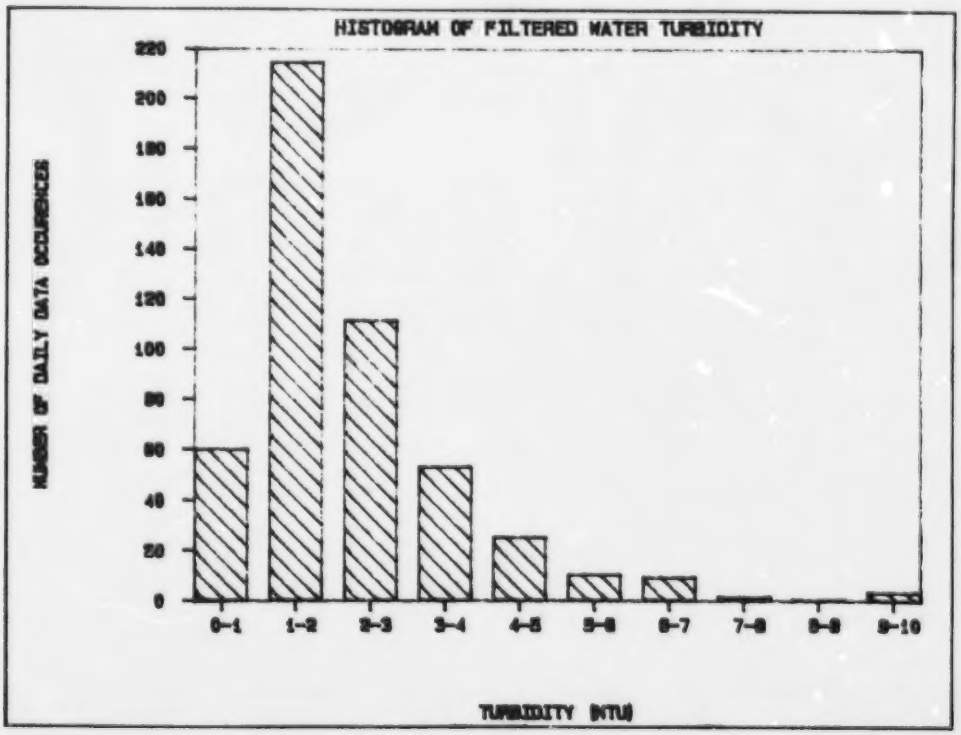


FIGURE 7
Limestone Water Treatment Plant

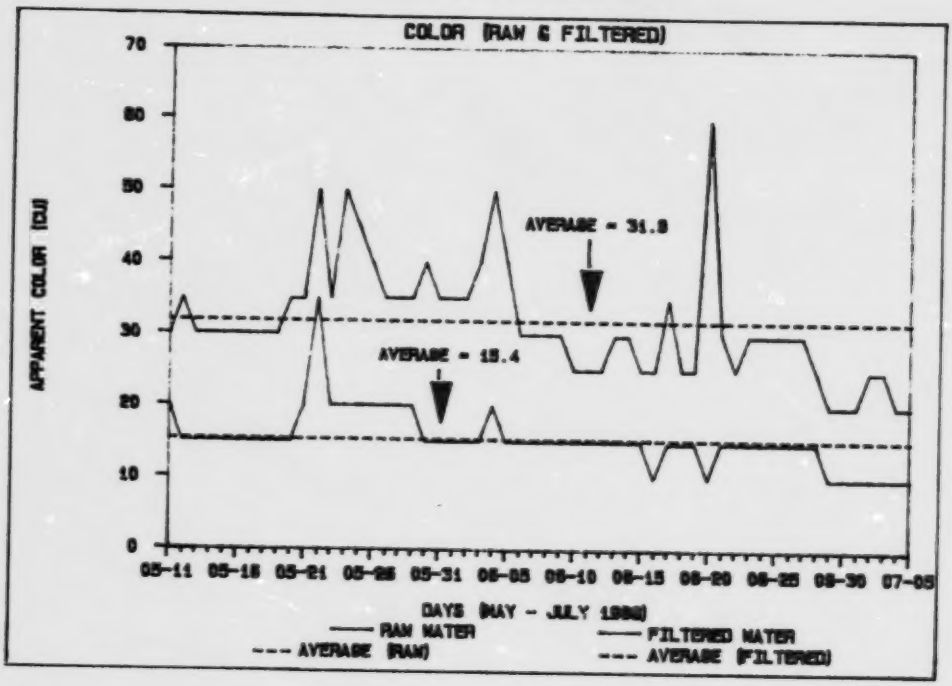
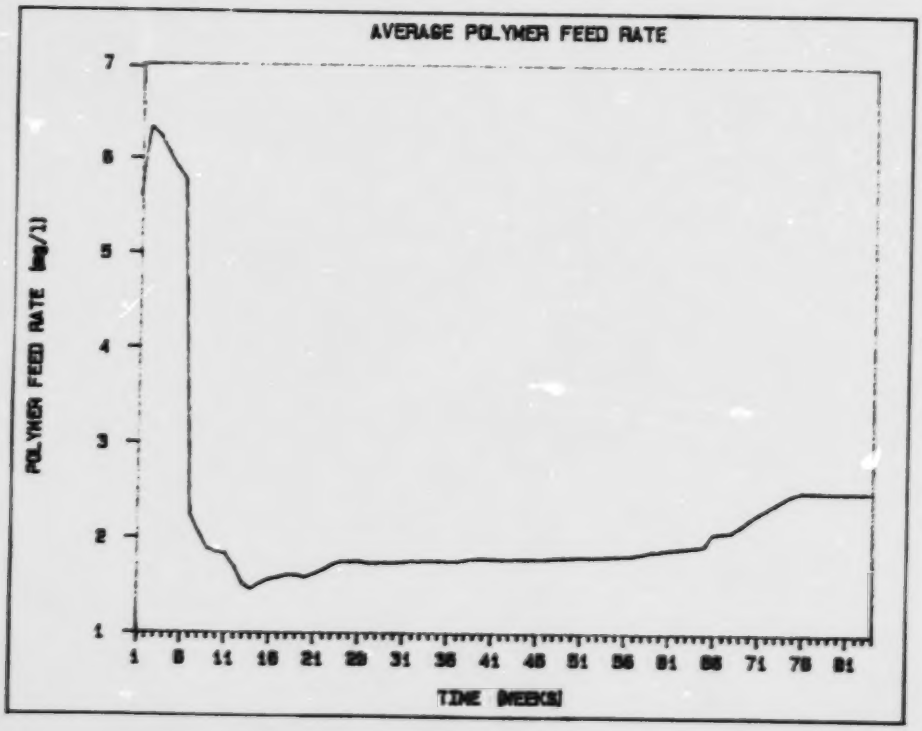


FIGURE 8
Limestone Water Treatment Plant



The preliminary proposal (submitted by A.J. Postker & Associates) to Manitoba Hydro had estimated that a conventional rapid mixing, flocculation, sedimentation and filtration plant would cost approximately one million dollars. The HRDB filtration alternative was estimated to cost about 50% of the conventional plant. The overall actual construction cost of the Limestone Water Treatment Plant was approximately $600,000 (Oct. 88). The direct costs represented 75% or $450,000 while engineering, transportation and overhead accounted for the remaining 25% or $150,000. The operating costs of the plant (excluding power requirements) has averaged approximately $8.00 per day for polymer and about 1 man-hour per day for inspections, maintenance and plant tests.

In conclusion, the plant has been successful in meeting the water quality standards, design criteria, and economic parameters specified for the project. Problems encountered during the commissioning of the plant were resolved in the field. The successful application of direct filtration at the Limestone Site has resulted in substantial capital cost savings. This is primarily attributed to the extensive pre-engineering analysis that was undertaken for the project.

ACKNOWLEDGEMENTS

Both the authors wish to thank Manitoba Hydro for its support by allowing complete access to the project data. Also the University of Manitoba, Department of Environmental Engineering, for the use of testing facilities. A special thanks to Hazel Monkman, Manitoba Hydro, for patience in typing the many revisions.

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BASIS AND PURPOSE OF CANADA'S NEW DRINKING WATER GUIDELINES

V.C. Armstrong, M.E. Meek and P. Toft
Environmental Health Directorate
Health Protection Branch
Department of National Health and Welfare
Ottawa, Ontario

ADMINISTRATIVE PROCEDURES

Canada's drinking water guidelines have been developed through collaboration between experts from federal and provincial departments of environment or health. This arrangement evolved from the distribution of powers as originally set out in the British North America Act of 1867, and subsequently the Constitution Act, 1987.

The 1978 Guidelines for Canadian Drinking Water Quality were prepared by a federal-provincial working group made up of representatives from each province, the Department of the Environment and the Department of National Health and Welfare. This working group, which reported through the Federal-Provincial Advisory Committee on Environmental and Occupational Health to the Conference of Deputy Ministers of Health, was disbanded in 1978 upon completion of its task. Because of the importance and continuing widespread interest in drinking water quality, a Federal-Provincial Subcommittee represented by all provinces, the Yukon and Northwest Territories and the Departments of National Health and Welfare and Environment was set up in 1986 as a standing committee. While this Subcommittee deals with a variety of factors that have a bearing on drinking water quality and treatment technology, the development of guidelines remains as its most important task. The current 1987 Guidelines for Canadian Drinking Water Quality represent the first step in revising the recommendations published in 1978 and lists guidelines for some 94 parameters.

The Guidelines for Canadian Drinking Water Quality are not legally enforceable standards unless they are embodied in legislation. Under the Occupational Safety and Health Regulations of the Canada Labour Code, employers must provide potable water that meets the 1978 national guidelines. Quebec and Alberta are the only provinces that have legislated drinking water quality standards, and these are based on the 1978 Canadian guidelines. Other provinces and territories, however, use the guidelines as the basis for controlling the quality of municipal supplies.

SELECTION OF PARAMETERS

Historically, the primary aim of the water supply industry was to provide water free from bacterial contamination. Later attention was given to dissolved inorganic substances many of which originate from natural sources. Except for a few pesticides, the organic content of drinking water was associated mainly with problems of taste and odour. It is only in the past decade that interest has been directed more to the presence of synthethic organic substances. The evolution of standards (or guidelines) in Canada has mirrored this widening interest. Thus, while the 1968 Canadian Drinking Water Standards and Objectives included specifications for some health related metal contaminants, radioactivity and a number of pesticides, emphasis was given to the aesthetic and operational aspects of drinking water. In 1978, recommendations were derived for 57 parameters of which 42 were chemical substances; fifteen pesticides and three other synthetic organic chemicals were listed.

Since 1978, advances in analytical methods have resulted in the discovery of a large number of organic chemicals that had previously gone undetected in drinking water supplies. Several hundred such chemicals have now been reported in Canadian supplies. Government and international agencies have responded by assessing the need for standards or guidelines for a wide variety of organic substances. It would be unreasonable to set guidelines for all the chemicals that have been reported in Canadian supplies. A substance was considered for inclusion in the 1987 Canadian guidelines if it had been frequently detected in drinking water and found at relatively high concentrations, if there was evidence that the substance causes adverse effects at low doses, and if the structure was similar to a known toxic chemical. Chemicals which appeared to be of interest only in a few specific areas of the country were usually not listed in the guidelines.

The Guidelines for Canadian Drinking Water Quality 1987 include recommendations for some 94 parameters. The total number of pesticides and synthetic organic chemicals, or groups of such chemicals, for which recommendations have been developed, is now 55, increased from 18 in 1978. Table 1 is a list of organic chemicals which are included in the new Guidelines.

TABLE 1
Organic Substances Include in the
Guidelines for Canadian Drinking Water Quality 1987

	MAC*	AO**
Benzene	0.005	
Benzo[a]pyrene	0.00001	
Carbon tetrachloride	0.005	
1,2-dichlorobenzene	0.2	≤0.003
1,4-dichlorobenzene	0.005	≤0.001
2,4-dichlorophenol	0.9	≤0.0003
Pentachlorophenol	0.06	≤0.03
2,3,4,6-tetrachlorophenol	0.1	≤0.001
2,4,6-trichlorphenol	0.005	≤0.002
Dichloromethane	0.05	
Ethylbenzene	-	≤0.0024
Gasoline	-	
Nitrilotriacetic Acid (NTA)	0.05	
Toluene		≤0.024
Trihalomethanes (THMs)	0.35	
Xylenes		≤0.3

* Maximum Acceptable Concentration (mg/L)
** Aesthetic Objective (mg/L)

Particular attention was paid to the selection of pesticides, because many of them are highly toxic and because of the fact that their mode of use can lead to contamination of water sources. Approximately 100,000 tonnes of pest control products are used annually in Canada of which 33,000 tones are used for agricultural purposes. Forty-two pesticides were selected for inclusion in the new guidelines - 20 insecticides and 22 herbicides. These 42 substances account for more than 75% of the quantity of pesticides used in Canadian agriculture. Ten of them were listed in the 1978 guidelines and 32 are new. The selection was based on use pattern and environmental behaviour, as well as the criteria decribed above. Guidelines have so far been developed for 35 of these 42 pesticides (Table 2).

TABLE 2
Pesticides Included in the Guidelines for Canadian Drinking Water Quality 1987

	MAC[a]	IMAC[b]	AO[c]
Aldicarb	0.009	–	–
Aldrin + Dieldrin	0.0007	–	–
Atrazine	–	0.06	–
Azinphos-methyl	0.02	–	–
Bendiocarb	0.04	–	–
Bromoxynil	–	0.005	–
Carbaryl	0.09	–	–
Carbofuran	0.09	–	–
Chlordane	0.007	–	–
Chlorpyrifos	0.09	–	–
Cyanazine	–	0.01	–
2,4-D	0.1	–	–
DDT + metabolites	0.03	–	–
Diazinon	0.02	–	–
Dicamba	0.12	–	–
Diclofop-methyl	0.009	–	–
Dimethoate	–	0.02	–
Diquat	0.07	–	–
Diuron	0.15	–	–
Endrin*	–	–	–
Glyphosate	–	0.28	–
Hepatachlor + Heptachlor epoxide	0.003	–	–
Lindane	0.004	–	–
Malathion	0.19	–	–
Methoxychlor	0.9	–	–
Methyl-parathion	0.007	–	–
Metolachlor	–	0.05	–
Metribuzin	0.08	–	–
Paraquat	–	0.01	–
Parathion	0.05	–	–
Phorate	–	0.002	–
Simazine	–	0.01	–
2,4,5-T	0.28	–	$\leq$0.02
2,4,5-TP*	–	–	–
Temephos	–	0.28	–
Terbufos	–	0.001	–
Toxaphene*	–	–	–
Triallate	0.23	–	–

*Proposed for deletion

a] Maximum acceptable Concentration (mg/L)
b] Interim Maximum Acceptable Concentration (mg/L)
c] Aesthetic Objective (mg/L)

Table 3 lists other organic substances and pesticides currently being examined and for which guidelines may be included at a later date.

TABLE 3
Additional Organic Substances Under Review

Alachlor	PCBs
1,2-Dichloroethane	Picloram
1,1-Dichlorethylene	TCA
Dinoseb	Tetrachlorethylene
Dioxins/Furans	1,1,1-Trichloroethane
Linuron	Trichlorethylene
MCPA	Trifluralin

SCIENTIFIC BASIS FOR DRINKING WATER GUIDELINES

Two different approaches were used to derive the health-based maximum acceptable concentrations (MACs). For most substances it is believed that a threshold level exists, that is a level below which no harm will result even over a lifetime of exposure. Toxicological data, normally obtained from animal studies, were used to arrive at an accetpable daily intake (ADI) calculated by dividing a "no-observed-adverse-effect level" (NOAEL), or "lowest-observed-adverse-effect-level" (LOAEL) in animals by an uncertainty factor. The magnitude of the uncertainly factor depends on the quality and quantity of the health data available and typically ranges from 100 to 5,000. Since drinking water is not the only source of exposure to chemicals, account was taken of exposures that result from other sources. The calculated ADI for each parameter was apportioned between the exposure routes, that is air, food and water. For example, twenty percent of the ADI for each pesticide was allocated to drinking water and 80% to food. Derivation of the guideline was also based on an average daily intake of 1.5 litres of water by a 70 kg adult.

For certain toxic effects, notably carcinogenesis, it is assumed, that there is some probability of harm at any level of exposure i.e., that no threshold exists. For carcinogens, it is considered inappropriate to calculate an ADI value; rather the risk posed by consuming such substances at the low concentrations found in drinking water is computed by extrapolating results from experiments in which high doses are administered to laboratory animals. These extrapolation procedures are, however, subject to a high degree of uncertainty due to the many, and sometimes tenuous assumptions made in developing the mathematical models, for example the mechanism of the toxic effects and biological differences between man and animals. Therefore, for carcinogenic substances, guidelines were set at levels which are measurable and which are attainable by employing available treatment technologies, the general principle being that exposure to carcinogens should be kept as low as practicable.

Maximum acceptable concentrations were set as low as practicable, by consideration of the following factors:

- the MAC must be achievable by available water treatment methods at reasonable cost.
- wherever possible, the upper 95% confidence limit for the lifetime cancer risk associated with the MAC was less than 10^{-5} to 10^{-6}, a range that is generally considered

to be "essentially negligible". In cases where intake from sources other than drinking water (e.g. food, air and consumer products) was significant, the upper 95% confidence limit for the lifetime cancer risk associated with the MAC was less than or equal to 10^{-6}.

- the MAC must also be reliably measurable by available analytical methods.

Should the estimated lifetime cancer risks associated with the MAC be greater than those judged to be essentially negligible an "interim maximum acceptable concentration" (IMAC) would then be set with the intention that a more stringent recommendation be made following any improvements made in analytical methodologies or treatment technologies.

Thus for carcinogenic chemicals the approach adopted is, in essence, a blend of estimating the magnitude of the particular health effect, with consideration of the feasibility of reducing the risk to levels which are acceptable from both economic and societal viewpoints.

It is not always possible to clearly designate a substance as "not carcinogenic" or "carcinogenic". Where available data indicate the possibility of carcinogenic effects in man the MAX was derived from an ADI incorporating an additional factor to allow for limited equivocal evidence of carcinogenicity.

FUTURE WORK

Work is continuing on the development of additional guidelines and the revision of existing ones. The Federal-Provincial Subcommittee on Drinking Water will continue to add to, delete from or revise the 1987 Guidelines, with updated guidelines being issued more frequently, perhaps as often as every year. The scientific rationale for each of the published guidelines will also be made available and kept up-to-date on a continual basis.

PHYSICAL, CHEMICAL AND BIOLOGICAL WARFARE AGAINST ALGAE

Hans G. Peterson, Ph.D.
and
S.M. Swanson
Environmental Division
Saskatchewan Research Council
Saskatoon, Saskatchewan

INTRODUCTION

This research has been carried out on farm dugouts [small reservoirs with 2 to 5 million litres of water], but several aspects may be applicable to most shallow water bodies on the Canadian prairies.

Saskatchewan farm dugouts are nutrient-rich water bodies where production of algae will be considerable from May to October every year. Depending on climatic conditions, nutrient conditions and the treatment history of the studied dugouts, the dugouts will be dominated by either blue-green algae [cyanobacteria] or green algae. The blue-green algae are referred to as cyanobacteria in current scientific literature and our use will conform with this.

There are two types of algal bloom problems in prairie farm dugouts, green algal blooms and cyanobacterial blooms. Most dugouts are sufficiently nutrient rich to produce and maintain both types of blooms during the summer months. Severe green algal blooms are generally "manmade" through the over-use of bluestone [copper sulphate], which kills off most organisms including algal grazers, but not copper tolerant green algae. With all competition gone, these opportunistic, fast-growing algae will rapidly dominate a dugout. Chemical control of green algae may not be possible, but biological control through encouragement of grazing organisms is often quite successful.

Problem cyanobacteria are generally slow growing and their ability to dominate dugouts is based on low loss rates and the ideal physical and chemical conditions that exist in most Saskatchewan farm dugouts. These organisms can be controlled by copper sulphate levels that are up to five times lower than those previously recommended by government agencies. It is often difficult for a farmer to distinguish between green algal and cyanobacterial blooms and application of copper to a green algal bloom will generally increase these blooms, and even low level treatments of cyanobacterial blooms may trigger green algal blooms within 10 days after copper application. An additional problem with cyanobacteria is that some strains give off potent toxins when they die and decay. No chemical treatment [including chlorination] will diminish the potential toxicity problem with cyanobacteria. Therefore, presently used chemical treatments need more research to be effective.

In contrast to chemical treatments, biological and physical methods show great promise. These methods have totally eliminated algal problems in some instances in our study. These treatments are more expensive and require some work input by the farmer, but chemical dugout treatment or no treatment at all will most likely result in algal blooms for extended periods of time from May to September.

Green Algal Blooms

Typical blooms of copper tolerant green algae occur in dugouts with a history of copper treatments. These green algae blooms flourish because the copper also kills zooplankton, which would normally help control the algae by grazing. These blooms will diminish in magnitude if copper treatments are low enough to allow zooplankton populations to survive. Chemical control of green algal blooms is often not possible and a strategy of maintaining an ecologically balanced dugout should be used to minimize such blooms. Nutrient reductions should also be used as a means of limiting the size of potential blooms. Typical of these blooms are explosive developments with an even distribution of algae throughout the water column. The algae are small; therefore, they may pass through commercially available filtration equipment creating tap water that looks like lime juice. These algae will most likely not produce any toxic effects in humans or livestock.

Cyanobacterial Blooms

Cyanobacteria are able to fix atmospheric nitrogen. They are most likely to dominate farm dugouts when water temperature, pH, incident radiation, and phosphorus content are high and the dissolved nitrogen reserves required by other algae have been exhausted. In contrast to the green algae, the growth rates of colony forming cyanobacteria are often low. The reasons for their prominence and considerable biomass in prairie waters are based on ideal physical and chemical conditions coupled with low loss rates. Cyanobacteria can continually form new biomass at a low rate without losing previously formed biomass. Therefore, explosive growths of colony-forming problem cyanobacteria common on the prairies, Aphanizomenon sp., Anabaena sp., and Microcystis sp., are unlikely. Their distribution in the water column may, however, change rapidly, and evenly distributed colonies may form surface scums depending on the physical conditions. Zooplankton will only at cyanobacteria when the colonies are quite small; therefore, zooplankton control of cyanobacterial blooms is not possible. Copper sulphate is an effective algaecide for cyanobacteria, but copper sulphate use must be restricted to low levels if green algal problems are to be minimized. It is difficult to establish optimal copper dosages for individual dugouts and cyanobacterial species since even low level dosages may be accompanied by subsequent green algal problems.

RESULTS AND DISCUSSION

Chemical Treatments

First, we will address over-treatment with copper sulphate and its consequences. The following case history illustrates the general sequence of events in a Saskatchewan farm dugout during the summer.

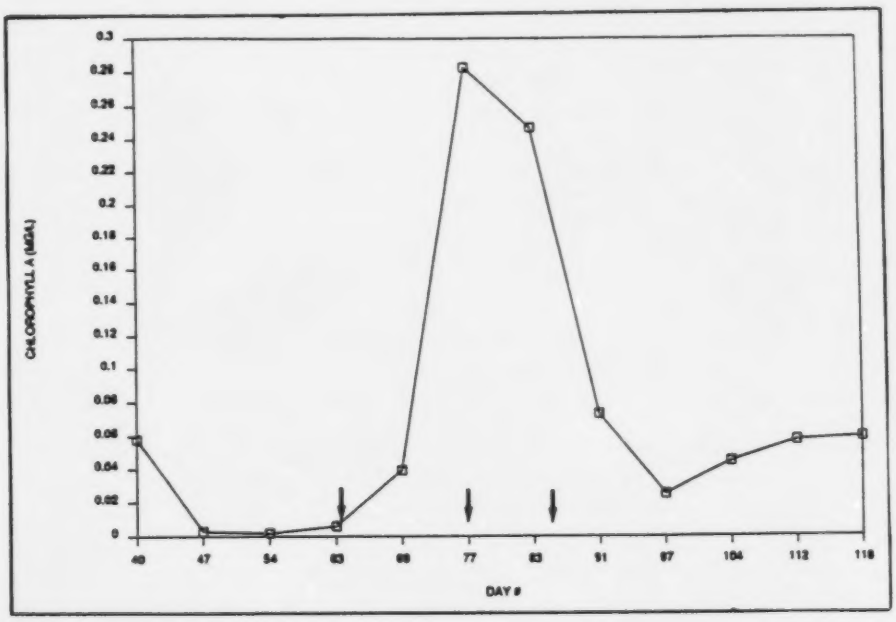
It is late July and the dugout water quality has been quite good. The farmer has not used bluestone (copper sulphate) for several weeks and the dugout has built up a considerable quantity of zooplankton. However, the farmer notices "finger nail clippings", characteristic of a type of cyanobacteria, Aphanizomenon, throughout the dugout. He follows standard practice by treating with 5 lbs. of bluestone per 500,000 gallons of water.

The arrows in Figure 1 indicate when bluestone was applied. The farmer detected the Aphanizomenon when the biomass was quite low, but 10 days after bluestone treatment the phytoplankton biomass had increased 50 times. He managed to get rid of the Aphanizomenon, but the new algae were presenting him with other problems. The algae were small (less than 5 um in

diameter) and were passing through commercially available filters. He therefore treated his dugout again with bluestone. The algae did not increase in biomass, but they did maintain their high level, and by now the farmer was really frustrated and went out one more time with more bluestone. This time the algal biomass was actually declining and the farmer finally saw the effects of bluestone, or so he believed.

FIGURE 1

Algal Biomass, Chlorophyll a,
from July to Mid September 1987 in Dugout #8,
The Arrows Indicate When Bluestone was Applied



By looking closer at the nutrient cycles (Figures 2 and 3) during the bloom, it became clear that phosphate was always at sufficient levels, but the inorganic nitrogen was reduced to low levels. The nitrogen (N) reserves had been depleted; therefore, further biomass increases would have to rely on N inputs from external or internal (sediment) sources. Only rarely do we see considerable external inputs of nutrients during the summer; most precipitation percolates directly into the ground and it is only during severe storm events that the dugouts gain water and external nutrients. Thus, the decline in algae was not caused by the copper but by lack of N.

FIGURE 2

Dissolved Phosphate, From July to Mid September 1987 in Dugout #8.

The Arrows Indicate when Bluestone was Applied

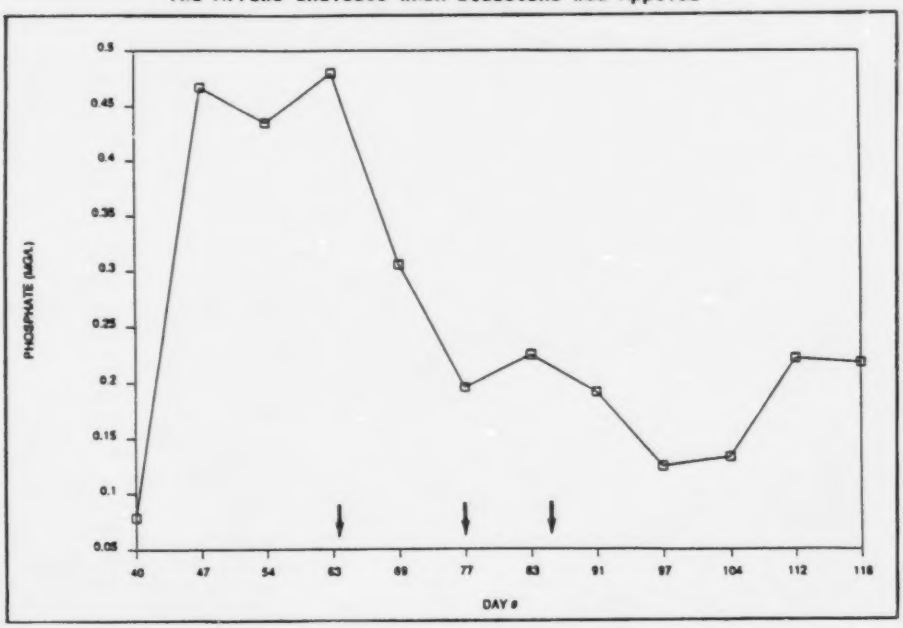
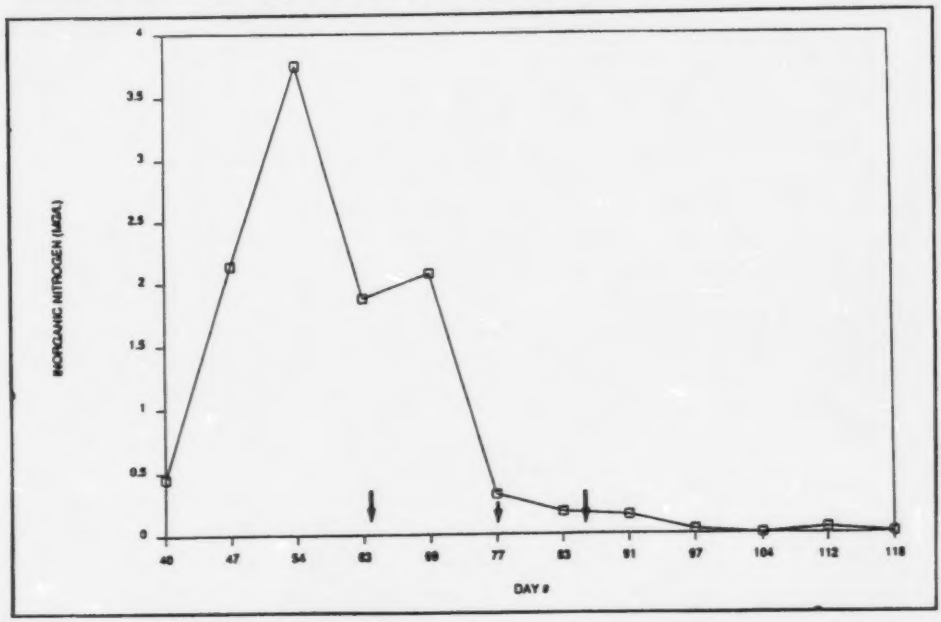


FIGURE 3

Dissolved Inorganic Nitrogen, From July to Mid September 1987 in Dugout #8.

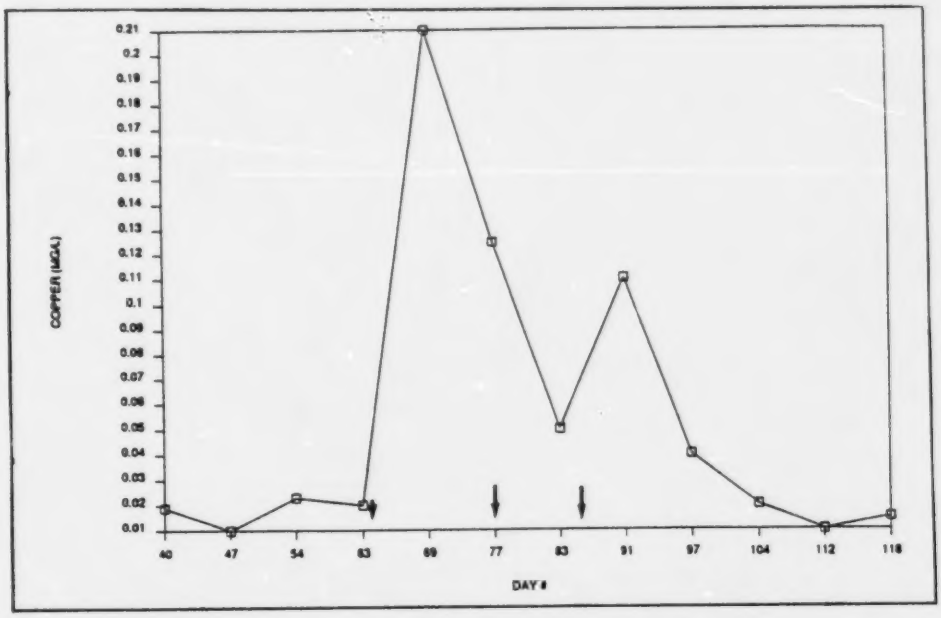
The Arrows Indicate when Bluestone was Applied



What did the copper (Cu) actually do to the chemistry and biology of the dugout? The dissolved levels of Cu (Figure 4) show that the initial Cu dose did produce high levels of dissolved Cu, but subsequent doses did not produce increased dissolved Cu levels. A considerable amount of Cu was taken up by the phytoplankton and subsequently sedimented out. The expected dissolved level that will be reached in a dugout is therefore strongly dependent on the algal biomass present at the time of application.

FIGURE 4

Dissolved Copper, From July to Mid September 1987 in Dugout #9.
The Arrows Indicate When Bluestone was Applied.



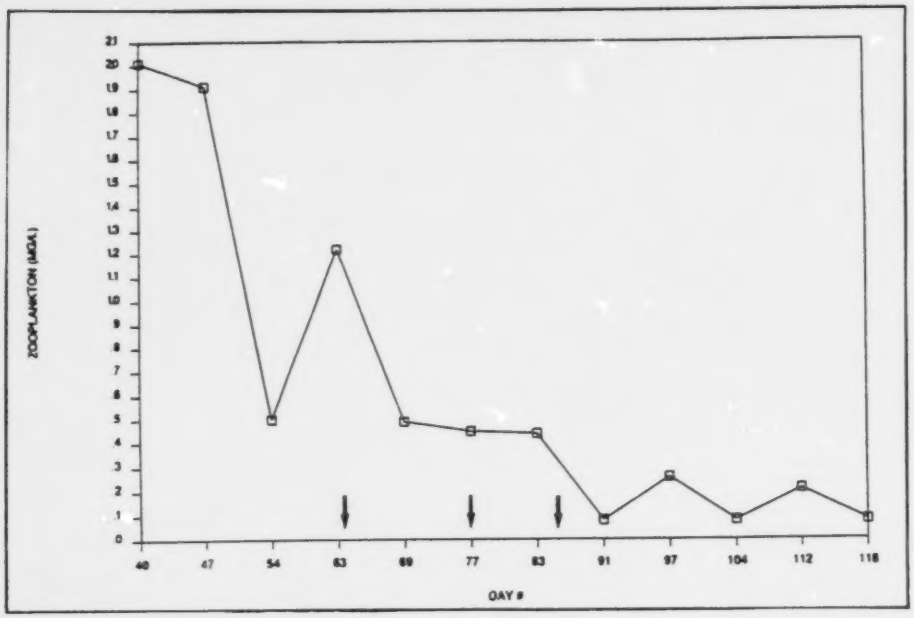
Zooplankton were also affected by the Cu treatment (Figure 5). Before the treatment, zooplankton biomass was initially high, then it started to decline due to lack of food; then a recovery occurred just before the first Cu treatment. Zooplankton biomass declined strongly after the first Cu treatment. Zooplankton biomass remained low despite ample food supply; further Cu treatments kept these herbivores at low levels.

In summary, the Cu treatment killed off the cyanobacteria and zooplankton, causing copper tolerant green algae to rapidly dominate the dugout. Copper was totally ineffective in controlling the green algae. The decline in algae that was seen was caused by a lack of nitrogen. The Cu was actually exacerbated the situation by killing herbivorous zooplankton that would otherwise have helped control the algae.

This year we treated several dugouts with low level copper sulphate with a good success rate in killing cyanobacteria. However, even at these low application rates green algae were frequently stimulated.

FIGURE 5

Zooplankton (Algal Grazers) Biomass.
From July to Mid September 1987 in Dugout #8.
The Arrows Indicate When Bluestone was Applied.



Other whole dugout treatments included calcium carbonate. The suggested mode of action of calcium carbonate is to precipitate algae and maintain lower phosphorus (P) levels in the water; this has not proven very successful. Severe algal problems continued after calcium carbonate treatments. Calcium carbonate treatments of late summer blooms did not even arrest growth; algal biomass showed strong increases six days after treatment. Similar failures to control algal blooms with calcium carbonate was experienced by the Manitoba Water Services Commission (Mike Tokarz, pers. comm.).

Reglone A (diquat) appeared to successfully control algal blooms in one of the test dugouts during 1987, and this farmer was allowed to continue this usage during 1988. This year, however, Reglone A treatments failed completely. Although Reglone A is a registered pesticide for use in drinking water supplies, we do not recommend it. Canadian guidelines for human use of diquat treated water allow consumption 24 hours after treatment. U.S. Environmental Protection Agency (EPA) Guidelines (using similar initial applications) allow consumption two weeks after treatment. EPA is concerned because recent scientific evidence shows that diquat is not reduced to acceptable drinking water levels (<0.01 ppm) in two weeks (Richard Manford, U.S. EPA pers. comm.). It is our opinion that the Canadian Guidelines for Diquat are severely out of line with current scientific knowledge and they should be revised before we can recommend its use in Saskatchewan farm dugouts.

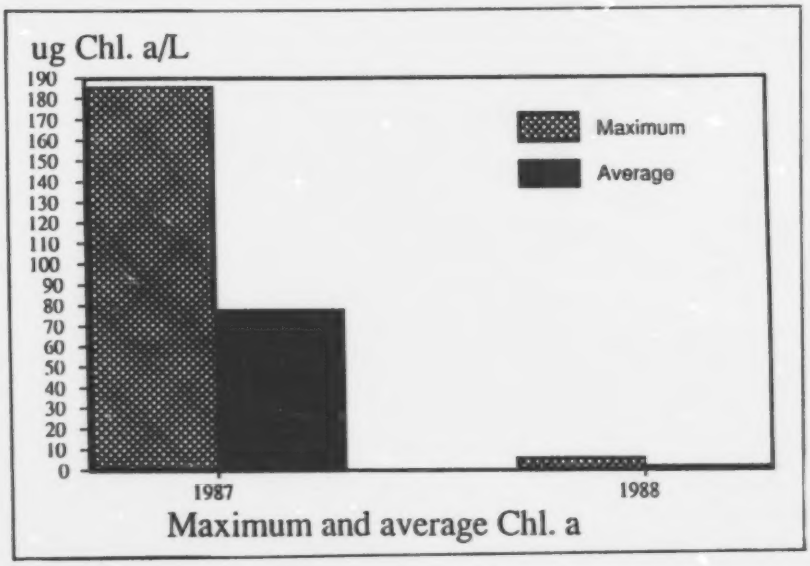
The use of the above described chemicals to treat whole dugouts will often not meet with success unless limited objectives are set, such as the removal of cyanobacteria and allowing green algal blooms. A number of other chemicals have been tested in limnocorral experiments at the Saskatchewan Research Council. We believe it is better to continue the search for effective chemicals using this type of smaller-scale experimentation, which is much more cost-effective than treating whole dugouts.

Physical and Biological Treatments

Physical and Biological treatments have, in contrast to chemical treatments, met with considerable success. One hundred percent shading eliminated the algal problem completely from a dugout that was dominated by copper tolerant green algal last year (Figure 6). This was carried out by using 6 mil black plastic that was tied to the shore with rope. There are two problems with this type of treatment; maintaining the oxygen levels in the dugout and damage by cattle, people and wind. Continuous aeration is necessary in covered dugouts with large quantities of organics, but it should be pointed out that covered dugouts cut the internally generated organics to very low levels; thus, it is expected that the oxygen demand will decline after this treatment strategy has started. Partial coverage was also studied; the aim was to pinpoint the minimum coverage required for satisfactory algal growth control. Partial coverage has the advantage of lower material costs and a lower risk of oxygen depletion in case of aerator failure. The cost for covering a dugout is around $200; the plastic in Figure 6 has been used for two seasons.

FIGURE 6

A Comparison of Maximum and Average Chlorophyll a Levels (Algal Biomass) From May to August in Dugout #1.
The Left Two Columns are for 1987 and the Right Columns are for 1988.
The Dugout Received Extensive Copper Sulphate Treatments During 1987 and Was Covered with Black Plastic During 1988



Biological shading combined with nutrient removal by using duckweed mats has also been quite successful. This treatment should be combined with fertilization of the dugout with nitrogen, which is required by the duckweed. This fertilization also leaves the nitrogen fixing cyanobacteria with less of a competitive advantage.

The Importance of Controlling Phytoplankton Blooms

There are several consequences of not being able to control algal blooms in drinking water supplies, all of which reduce the value of this resource. However, if we limit the degradation of water quality by phytoplankton to effects on human health and livestock production, one specific problem dominates, cyanobacterial toxins.

The cyanobacteria are "problem algae" because not only do they impart taste and odour to the water, they may also be toxic. When accumulations of cyanobacteria are consumed; for example, when cattle are allowed to drink directly out of a dugout, the results can be fatal. Around 20% of all cyanobacteria that have been tested for toxicity have been found to be toxic, but since blooms are often composed of more than one species, in excess of 50% of all cyanobacterial blooms so far tested have been found to be toxic (Codd et al. 1988). The toxicity of cyanobacteria in Canada has been documented in some cases (Gorham et al. 1964; Gorham and Carmichael 1988). Cyanobacterial toxins are either liver toxins (hepato-toxins) or neurotoxins (Carmichael 1988); they are chemically and biologically stable and detoxification is thought to be achieved by particulate adsorption and dispersion (Falconer, pers. comm.). When a large drinking water reservoir in Australia was treated with copper sulphate to kill the Microcystis bloom the human health effects of drinking that water was established for more than 700 people (Falconer et al. 1983; Falconer 1988). Liver damage was evident, but this was repaired several weeks after the disappearance of the bloom. It is the continued exposure to low level toxins that should be addressed. Yield reductions in livestock consuming water containing cyanobacterial toxins should be expected (Falconer, pers. comm.). We plan to start a major study on the production and fate of these toxins in Saskatchewan waters.

It is generally assumed that green algae do not present a health problem to livestock or humans. Infections (lymphadenitis) of cattle by Chlorella sp. (a common copper tolerant alga) has, however, been reported (Rogers et al. 1980). R. Guillard of Woods Hole Oceanographic Research Station has also isolated a Chlorella sp. that is toxic to oysters. It may therefore be prudent to concentrate on treatment or prevention strategies that reduce all phytoplanktonic algal blooms.

SUMMARY

Control of algae in waters used as drinking water supplies and for recreation has been elusive in recent years due to algal resistance or tolerance to commonly used pesticides. Success with a particular chemical in some lakes does not mean that the chemical will work in all lakes because of differences in physical, chemical and biological parameters among lakes. It is not surprising that a never-fail chemical has not been found given the presence of high numbers of algal species, all with specific, but differing requirements and with the ability to make use of available niches in an ecosystem with relative ease. High nutrient inputs from catchment basins or internal regeneration of nutrients can cause large algae or aquatic plant populations, even when pesticides are present. Therefore, we must concentrate our efforts on channelling available nutrients into plant biomass that does not present a nuisance. This channelling must be combined with reductions in internal nutrient regeneration. Channelling of nutrients and

reductions in internal nutrient regeneration can be accomplished by combinations of chemical, physical and biological methods. Such integrated treatment approaches will provide long-term benefits, offsetting initial start-up costs.

ACKNOWLEDGEMENTS

This work was supported by the Saskatchewan Agriculture Development Fund. Saskatchewan Water Corporation was responsible for field sampling and technical assistance. The field sampling was carried out by Jan Palmier and Bill Anderson with Jim Kidd providing technical assistance. Mary Moody and Colleen Rickard of the Saskatchewan Research Council carried out the chemical analysis and data input.

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TRACE ORGANIC CONTAMINANTS IN THE CANADIAN ARCTIC

W.L. Lockhart and D.C.G. Muir
Department of Fisheries and Oceans
Central and Arctic Region
Winnipeg, Manitoba

INTRODUCTION

Several years ago biologists working in the Mackenzie River drainage began to receive complaints from DENE communities that something was wrong with the fish. Specifically the complaints were that livers of burbot (loche) (Lota lota) had become small and shrivelled and dark in colour (as compared to its normal large size and pale cream colour), and that muscle of whitefish (Coregonus clupeaformis and Coregonus nasus) had become soft and "watery" in texture. People who have eaten burbot liver traditionally in the past will no longer do so because of the unusual appearance of the livers. The timing of these complaints coincided with operations to expand production of oil at Norman Wells, and so the hypothesis was put forward that the condition of the fish might be related to pollution originating from the oil industry.

Inititally our investigation was aimed at determining whether the complaints about the condition of the fish might be consistent with sub-lethal injury resulting from exposure to oil. We also examined fish from the Mackenzie valley communities for signs of oil-related pathology, namely oil-inducible liver enzymes, and we tested fish in the laboratory to verify that Norman Wells oil would in fact induce the enzyme activities expected. We also examined the fish for chemical residues of hydrocarbons which might indicate exposure to oil. The results of those investigations were to confirm the validity of the complaints about the fish, but to argue that the cause was not oil from Norman Wells. In addition, we examined the fish for other chemical residues, and found widespread contamination with a number of organochlorine compounds. This latter problem may turn out to be more pervasive than the one we set out originally to examine.

METHODS

Methods used have been described by Lockhart et al. [16] and by Murray and Lockhart [19]. Fish were netted from several communities in the Mackenzie valley, and from "control" areas in Manitoba and northwestern Ontario for analyses for oil-inducible enzymes, and for residues of hydrocarbons and stable organochlorine contaminants.

Liver microsomal mixed function oxidases (MFO)

Livers to be used for microsomal mixed function oxidase measurements were dissected and frozen on dry ice shortly after removal of the fish from the water. Frozen livers were shipped to Winnipeg on dry ice and maintained at -60° until analyzed. For preparation of microsomes pieces were chopped from the frozen liver and these pieces were allowed to thaw at $2-4^{\circ}C$ until they were soft enough to be cut into smaller pieces with scissors. The small pieces were suspended with cold 0.02 M HEPES [4-(2-hydroxyethy)-1-piperazine-ethanesulfonic acid]/0.15 M KCl buffer (pH 7.5) using 4 mL buffer per g of tissue in cold glass tissue homogenizers and homogenized using 5-7 passes with a motor-driven teflon pestle. The homogenate was then centrifuged at 12000 x g at $2^{\circ}C$ for 20 min. to remove insoluble matter and the supernatant was further centrifuged at 105000 x g at $2^{\circ}C$ for 90 min to obtain a microsomal pellet. The pellet was washed and resuspended in HEPES/KCl buffer to give a protein concentration between 5 and 25 mgL^{-1}.

Protein in microsomal suspensions was measured by the 'Lowry' method as modified by Markwell et al [17] with bovine serum albumin as a standard. These suspensions were used for assay of enzymatic activities. The assay for aryl hydrocarbon hydroxylase (AHH) was based on that of Depierre et al. [6] as modified by Van Cantfort et al. [31] to measure the production of polar metabolites from tritiated benz[a]pyrene used as substrate. Ethoxyresorufin-O-deethylase (EROD) was measured by the deethylation of 7-ethoxyresorufin to yield resorufin which was detected either by the fluorometric procedure described by Burke and Mayer [4] and Prough, Burke and Mayer [26] or that of Pohl and Fouts [25].

Experimental induction of burbot MFO enzymes

Large burbot captured in Lake Winnipeg, Manitoba, in Oct./Nov., 1986, were maintained in the laboratory for several months where they were fed young trout and char. During 1987 groups of six or seven fish were taken and injected either with corn oil alone, or with one of several contaminants, including Norman Wells crude oil, dissolved (1:1) in corn oil. Six days after injection the fish were killed and analyzed for liver MFO activities.

Hydrocarbon residues

For the extraction of low-boiling hydrocarbons (mostly substituted benzenes) chopped tissue was extracted for three hours with a stream of warm (60°C) pre-cleaned air [19], similar in principle to procedures described by Berg [2] and by Reinert, Hunter and Sabatino [28]. Hydrocarbons were analyzed by capillary gas chromatography using a Varian Model 6000 instrument fitted both with a flame ionization detector.

Polycyclic aromatic hydrocarbons were extracted from blended portions of liver or muscle which was first boiled for four hr with methanolic KOH. The alkaline digest was extracted with hexane and then dried with Na_2SO_4 and cleaned up with a column of silica gel and alumina. The PAH fraction was eluted from the column with dichloromethane and then evaporated and taken up in acetonitrile for injection for injection into a Varian 5000 high-pressure liquid chromatograph fitted with ultraviolet and fluorescence detectors. These methods were based on earlier descriptions by Kinzer et al. [12] and Smith, Bagg and Bycroft [29].

Organochlorine residues

Fish tissues were homogenized by blending with dry ice in a blender, and 10-50 g of homogenized tissue was extracted in the same manner as for PAH, except that hexane was used instead of dichloromethane (DCM). The hexane extracts were taken down to a small volume on a rotary evaporator and then taken up in hexane:DCM (1:1) for gel permeation chromatography followed by Florisil chromatography to remove biogenic lipids [21]. After concentration the fractions were made to known volumes and analyzed by gas chromatography on a Varian model 6000 instrument, equipped with an electron-capture detector and a 60-m x 0.25 mm fused silica DB-5 capillary column. PCBs were quantified as individual isomers using standards from the National Research Council of Canada (Halifax laboratory), and chlordane, DDT, HCH and HCB were quantitated using authentic standards. Toxaphene peaks were quantitated by summing areas of 8 peaks identified as toxaphene-related by GC/MS, and multiplying by a response factor based on the area of the same 8 peaks in a toxaphene standard. (Organochlorine standards other than PCBs were obtained from the Canadian Wildlife Service, Ottawa, and from Ultra Scientific, Hope, Rhode Island, U.S.A.)

RESULTS AND DISCUSSIONS

Liver MFO enzymes

In the laboratory the liver enzymes (EROD and AHH) of burbot responded to oil injection as expected (Table 1), in common with previous reports from both field and laboratory studies with fish exposed to oil (24, 32, 10, 14). The EROD activities of oil-treated burbot were about 20-fold over the controls treated with corn oil only. Similarly the oil treatment increased AHH activities, although the increase was not as striking as with EROD. If the burbot from the lower Mackenzie River were in a state of chronic intoxication with Norman Wells oil, then we should have expected to see elevated activities of these enzymes, particularly EROD. However, inspection of the actual liver MFO activities showed no consistent pattern of induction of either enzyme activity over burbot taken remote from sources of petroleum pollution at Norman Wells (Figure 1). Based on this line of argument, it seems that the burbot from the Lower Mackenzie River were not chronically intoxicated with petroleum components with enzyme-inducing properties. The experiments with chlordane and toxaphene, however, showed no induction in the laboratory, and hence the enzyme activities make no comment on the biological implications of these contaminants.

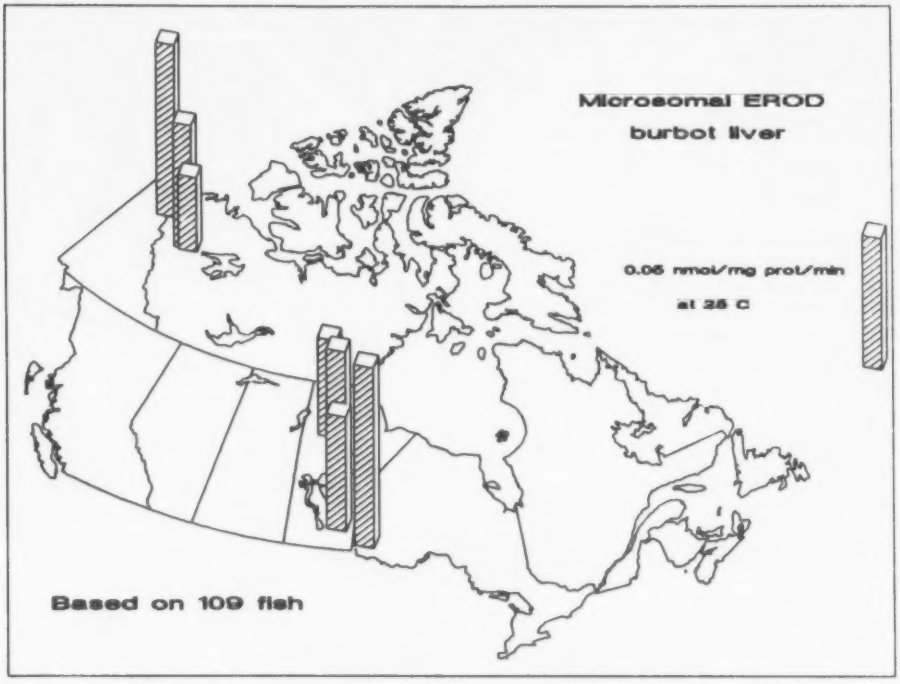
TABLE 1

Induction of liver microsomal enzyme activities (generally 7 fish per treatment group) following intraperitoneal injections of candidate inducing chemicals

	Mean Enzyme activity (nmol/mg protein/min at 25°C)					
INDUCER	N	AHH	S.D.	N	EROD	S.D.
Corn oil 1	7	.009	.0037	7	.066	.031
Corn oil 2	6	.010	.0024	7	.071	.026
Corn oil 3	7	.0061	.0037	7	.062	.032
Benz(a)pyrene	6	.31	.088	6	2.72	.937
Crude oil	6	.206	.038	7	1.23	.204
Phenobarbital	7	.0054	.0035	7	.047	.026
Chlordane	7	.0063	.0028	7	.056	.028
Toxaphene	7	.0071	.0031	7	.048	.024

FIGURE 1

Liver microsomal EROD activities
(umoles product formed per mg microsomal protein per minute at 25°C)
in burbot from several locations



Low-boiling hydrocarbons

The second line of investigation concerned low-boiling hydrocarbons, typically substituted benzenes, which are major components of the 'water-soluble fraction' of Norman Wells crude oil and other petroleum oils [20, 15]. Since these materials are taken up readily from water by fish, then traces of them might be detected in fish tissues and provide evidence of exposure to petroleum components. Among the most common materials in water-soluble fractions of oils are the xylenes, and these in fact were found in fish from the Mackenzie system (Table 2). There was a striking difference between the levels detected in open water vs. ice-covered water at Fort Good Hope (downstream from Norman Wells), but not at Fort Simpson (upstream from Norman Wells). In view of the volatility of these hydrocarbons it seems probable that they would volatilize in summer and not be transported far downstream. In winter, however, volatilization would be limited by the ice cover and they could then move downstream. The implication then is that a source of low-boiling hydrocarbons existed under the ice at some point between Fort Simpson and Fort Good Hope during the winter of 1984/85. The source could reasonably be hypothesized to be either effluents or natural seepages from the Norman Wells area.

TABLE 2

Low-boiling aromatic hydrocarbons (ng g^{-1}) in burbot muscle tissue under open water (October, 1985) and ice covered (April 1985 and 1986) conditions, upstream (Fort Simpson) and downstream (Fort Good Hope) from Norman Wells, N.W.T., Canada

		Fort Good Hope (Downstream)		Fort Simpson (Upstream)	
		April/85	Oct/85	Oct/85	April/86
Ethylbenzene	mean	49.6	7.3	7.8	4.8
	S.D.	26.4	6.1	4.0	4.8
	min	20.	1.5	2.	nd
	max	115.	25.	19.	12.5
	N	16	16	20	8
m-,p-Xylene	mean	185.	15.9	21.2	14.9
	S.D.	110.	10.2	12.5	13.3
	min	72.0	4.0	7.	nd
	max	499.	40.	57.	34.
	N	16	16	20	8

The low but positive values from the open water seasons appear to reflect a widespread presence of these compounds, since we have found similar levels from other locations remote from sources of oil pollution. For example, levels of low-boiling hydrocarbons from Lake Winnipeg off Hecla, (Manitoba, winter 1986) were similar to those for the Mackenzie sites in summer. It is not clear whether these hydrocarbons reflect pollution or some natural process. Reinert, Hunter and Sabatino (28) examined a small number of estuarine fish and shellfish from New Jersey and found up to 0.18 ppm (180 ng g^{-1}) of m- and p-xylene in them. Ogata and Miyake (22,23) associated an objectionable odour in fish from the coast of Japan with contamination by toluene. However, more recent studies have shown toluene to be produced naturally in lakes (11), but that does not seem to be the case with ethylbenzene and xylenes. It is not clear yet whether the low-boiling hydrocarbons in the fish represent a hazard to the fish or to the quality of fish as food.

Polycyclic aromatic hydrocarbons

Concentrations of most polycyclic aromatic hydrocarbons were determined by high-pressure liquid chromatography which had good sensitivity, but which did not resolve peaks as well as gas chromatographic methods. Generally PAH levels were under 10 ng g^{-1} (parts per billion), with the exception of those with relatively high volatilities (naphthalene and fluorene). Naphthalene was identified in 38 of 97 samples with the maximum concentration being 137 ng g^{-1}, while fluorene was found in 22 of the samples to a maximum of 180 ng g^{-1}. Burbot liver was more highly and consistently contaminated than either burbot or whitefish muscle. These results are in the about the same range as earlier results with fish from the Great Lakes (13), and, with the exception of naphthalene, they are generally lower than PAH in burbot from the Finnish archipelago (27).

Organochlorines

Organochlorine concentrations in burbot liver are given in Table 3 (taken from Lockhart et.al., 16). Burbot use the liver as a fat storage organ (up to 70 per cent fat) and consequently fat-soluble organochlorines become relatively concentrated there, with the most abundant residues being toxaphene, total PCBs and chlordane. There is no general world consensus on the amount of toxaphene that can be consumed safely by people, but two figures have been proposed. Sullivan and Armstrong (30) cited two earlier U.S. publications on the subject: in 1976 the U.S. Environmental Protection Agency estimated that the acceptable daily intake (a.d.i.) of toxaphene was 3.4 µg per kg of body weight per day; in 1977 the U.S. National Academy of Sciences gave the a.d.i. as only 1.25 µg per kg body weight per day. Thus a person weighing 70 kg might safety consume 87.5 ug per day using the lower estimate or 238 ug using the higher. On average the weights of liver required to furnish these amounts of toxaphene would be only about 110 go 293 g for the lower and higher a.d.i. values respectively. Taking the worst case of the highest concentration of toxaphene in liver (5.35 µg g^{-1}) the weights of liver required are only about 17 and 45 g for the two a.d.i. values. The average daily intake of toxaphene in the U.S has been estimated at only 1.59 µg per day from the concentrations found in typical food items (7). This amount would be supplied by about 2 g of liver from northern burbot.

TABLE 3

Organochlorines[1] (ng g^{-1} wet weight) in liver of arctic burbot[2] (1985/86), as compared with liver of burbot from Lake Winnipeg (1988)(from Lockhart et.al. 1987)

Source	CBz	HCH	DDT	Chlor dane	Toxa phene	Diel drin	PCB tetra	PCB penta	PCB hexa	PCB hepta	PCB octa
Arctic											
Mean	17.1	13.9	43.2	83.1	815	5.9	20.5	36.3	49.9	27.0	5.0
S.D.	15.9	9.7	48.5	109.0	1241	4.8	26.4	31.2	42.2	21.3	6.4
min	1	4	4	5	27	nd	3	12	14	5	nd
max	71	36	219	241	5353	20	117	136	165	86	28
(n=18)											
Lake Wpg											
mean	9.1	14.7	259	38.5	387	9.8	116	249	359	240	80.4
S.D.	4.9	8.5	292	40.1	542	6.9	124	303	414	287	76.2
min	2	4	28	6	42	2	23	50	54	35	8
max	15	27	853	112	1655	21	347	922	1265	888	240
(n=8)											

[1] CBz - Sum of tetra-, penta-, and hexachlorobenzenes
HCH - Sum of α-, β- and γ-hexachlorocyclohexanes
DDT - Sum of p, p'-DDT, p,p'-DDD, p,p'-DDE and o,p-DDT
Chlordane - Sum of chlordane-related peaks, calculated as chlordane
Toxaphene -calculated using 8 peaks in the GC profiles of toxaphene standard and of the samples
PCB (tetra) - Sum of tetrachloro-PCB congeners.
Sums of penta-, hexa-, hepta- and octachloro- congeners are also shown.

[2] Arctic fish from Arctic Red River (4), Fort Franklin (2), Fort Simpson (4), Fort Good Hope (4) and Fort McPherson (4).

Comparing the residues in Lake Winnipeg burbot with those of the northern burbot in Table 3, it is clear that most residues are higher in the southern fish. The exceptions are HCH, chlordane, and toxaphene which all appear to be as high or higher in the northern fish. Using a larger data set, some north/south trends emerge. We have analyzed 83 burbot, and normalized the values for fat content, with the result that some significant trends in residues as a function of latitude are apparent. Table 4 gives correlation coefficients between residues and latitude for the different groups of organochlorines. Figure 2 shows one of the clearer examples, namely DDT in burbot liver, as a function of latitude North.

TABLE 4

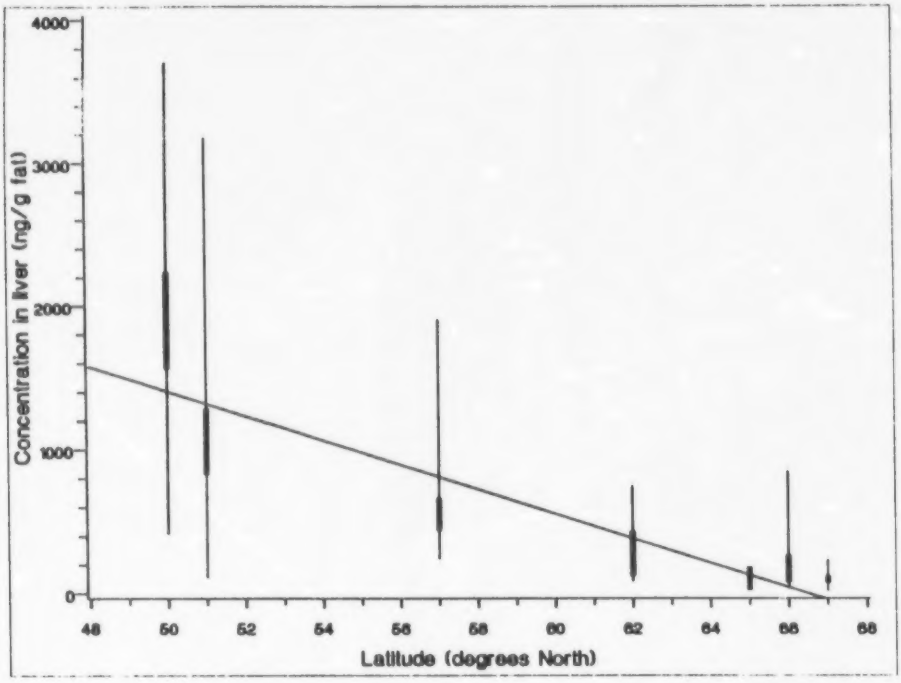
Correlation coefficients between organochlorine compounds in burbot liver and latitude of sites where burbot were taken, based on the analysis of 83 fish

Organochlorine group	Correlation with latitude	Probability
∑HCH	−0.47	≤0.0001
∑DDT	−0.61	≤0.0001
Dieldrin	−0.66	≤0.0001
∑Chlorobenzenes	+0.18	ns
Toxaphene	+0.09	ns
Chlordane	−0.28	0.024
Trichloro-PCBs	−0.05	ns
Tetrachloro-PCBs	−0.25	0.048
Pentachloro-PCBs	−0.34	0.0067
Hexachloro-PCBs	−0.44	0.0004
Heptachloro-PCBs	−0.44	0.0003
Octachloro-PCBs	−0.56	≤0.0001

These correlations give rise to some interesting speculation regarding sources of the organochlorines. If the source of them is past use in temperature latitudes of North America, then we might expect to see a gradient with residues declining from south to north, and hence the negative correlations with latitude. However, that explanation fails for cases where no clear gradient exists (toxaphene, chlorobenzenes, trichloro-PCBs). In these cases there may be additional sources or they may move a different rates or by different mechanisms. The consistent increase in correlation with degree of chlorination within the PCB group is particularly interesting (Table 4) because these presumably all have the same source. The Arctic burbot appear to have become as contaminated as southern burbot with the more volatile PCB congeners measured (trichloro), but less contaminated with the least volatile ones measured (octachloro). If these do in fact originate from the same sources, then it implies that volatility may be controlling the rate of distribution of these materials throughout the planet.

FIGURE 2

DDTs in Burbot Liver (normalized to ng per g fat) vs latitude for burbot from 10 locations ranging from the Experimental Lakes Area, Ont. to Fort McPherson, N.W.T.



Mean organochlorine residues for burbot liver (freshwater) may be compared with the residues in marine animal tissues in Table 5 (adapted from Muir et.al., (8)). The comparison is not fully adequate because of biological differences in species, age, fat content, etc. of different tissues, but it does permit an overview of the potential for transfer from the animals to humans consuming them. The profile of toxaphene peaks was changed more extensively from that of the standard in tissue of marine mammals than in fish, making quantitation in the mammals more uncertain, hence the absence of mammalian toxaphene figures from Table 5.

TABLE 5

Mean organochlorine residues (ng g^{-1}) in tissues of Arctic marine fish, seals and bears from Admiralty Inlet, N.W.T. (adapted from Muir et.al., (1988))

Species	Tissue	CBz	HCH	DDT	Chlordane	Toxaphene	Dieldrin	Sum of PCBs
Arctic cod	Muscle	3	18	2	2	23	1	3
Ringed seal	Blubber	32	227	1334	463	-	74	794
Polar bear	Fat	446	330	210	2971	-	375	4572

Clearly the burbot liver is much more highly contaminated than muscle of arctic cod. (Indeed burbot liver is much more highly contaminated than muscle of the same burbot.) Both seal blubber and bear fat are also more contaminated than the arctic cod. These organochlorines are distributed throughout the Arctic (and the Antarctic) in areas remote from any known use of the compounds. Organochlorines and polycyclic aromatic hydrocarbons have been measured in Arctic air samples (3,5,9) and recently in snow from the Agassiz glacier (8). These contaminants and other materials like pollen (1) are being dispersed by air masses which move to and from the Arctic. The most stable of these materials persist for long periods and some of them end up in fish and marine mammals from which they can be passed on to the people.

From the subsistence fishery viewpoint for coastal communities, the seals and whales probably represent the greatest source of organochlorines in the diet. Taken together the burbot liver data and the marine animal data suggest that northern people maintaining a traditional lifestyle with heavy reliance on fish and marine mammals may have one of the highest intakes of organochlorines of any group in North America.

ACKNOWLEDGEMENTS

Support for these studies was provided jointly by the Department of Fisheries and Oceans and the Department of Indian Affairs and Northern Development. Technical assistance by C.L. Baron, B.N. Billeck, R.A. Danell, C.A. Ford, N.P. Grift, R.V. Hunt, R. Lypka, D.A. Metner, and D.A.J. Murray is acknowledged.

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REHABILITATION/UPGRADING ALTERNATIVES FOR A SEWER SYSTEM WITH SERIOUS INFLOW/INFILTRATION

Tom Field, P.Eng.
David W. Atkinson, P.Eng.
CH2M Hill Engineering Ltd.

Alec Waters, P.Eng.
Alberta Transportation & Utilities

INTRODUCTION

The Town of Canmore is situated in southwestern Alberta at the eastern entrance to Banff National Park. Nestled within the Rockies, its setting is spectacularly scenic. Canmore began its life in the latter half of the nineteenth century as a coal mining centre, and the town still has some interesting relics and remnants of that era.

Nowadays, Canmore's main economic activity for its 4,000 plus residents is tourism. Its closeness to the ski resorts in Banff National Park makes it a major winter recreation destination. This year it was the venue for the cross country and biathlon events of the XVth Winter Olympic Games. The Nordic Centre, constructed for these games, is recognized as one of the most modern in the world and will continue to attract events of international calibre.

BACKGROUND

Canmore's sewer system dates back to 1957 when approximately 9000 m of sanitary sewers, ranging in size from 200 to 300 mm in diameter, were installed in the town. The material used was vitrified clay tile (VCT) plain end pipe joined with single strap coupling. The sewer system has since been extended into the newer areas where polyvinyl chloride (PVC) was generally used.

Excessive inflow/infiltration (I/I) was first detected in 1978 when wastewater flow measurements were initiated because the town was planning to replace the existing sewage lagoon with a new sewage treatment plant. In 1981 the town undertook an I/I monitoring study which indicated the main problems were in areas serviced with VCT pipe. TV inspections during 1980 to 1983 showed leaking manholes, open pipe joints, cracked pipe, and faulty service connections as the main source of infiltration.

Repair work, including pressure grouting of leaking manholes and pipe joints as well as sliplining of one sewer segment, was carried out in 1983/84. Further TV inspections were done in 1985. While the grouting was found to be effective, additional deterioration in the form of cracks was observed in the VCT sewers.

The volume of I/I, significant year-round, increases as the water level in the Bow River rises with peak flows occurring in the June/July period. Minimum flows occur during the October/November and February/March periods.

The impact of increasing I/I within the sanitary sewer system has now reached serious proportions. The sewer lines are subject to surcharging, resulting in flooded basements on occasion. The hydraulic capacity of the town's sewage treatment plant is exceeded, which requires bypassing of significant flow to avoid flooding.

While the rehabilitation work described above reduced the infiltration from some areas, problems with sewer pipe capacity and treatment plant overload still exist. CH2M Hill was retained to undertake a comprehensive I/I evaluation and sewer system rehabilitation/upgrading study. The study objective was to develop cost-effective corrective measures for reducing I/I into the collection system.

METHODOLOGY

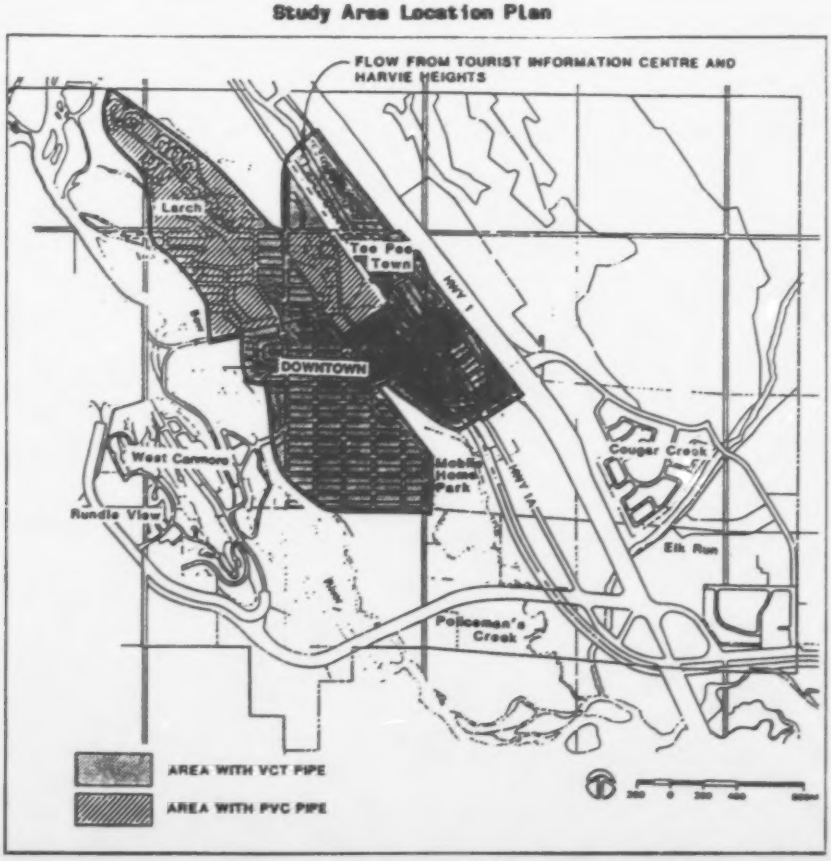
The methodology adopted to investigate the I/I problem and recommend corrections was:

1) Review existing data.
2) Carry out the necessary field investigations (flow monitoring, groundwater measurements, surveys).
3) Locate and quantify I/I.
4) Analyze the capacity of collection systems.
5) Review applicable sewer rehabilitation technology.
6) Propose alternative upgrading plans and review for cost-effectiveness.
7) Recommend an implementation plan.

STUDY AREA

The study area location plan is shown in Figure 1. It shows the town's sewer system located southwest of the Trans Canada Highway between the highway and the Bow River. Most of the sewer mains in this area are below the groundwater level, especially during the summer months.

FIGURE 1
Study Area Location Plan



The Rundle View and West Canmore areas southwest of the river and the Cougar Creek and Elk Run areas northeast of the Trans Canada Highway are not included in the study area because these areas do not receive significant I/I.

The existing system consists of a network of gravity sewer mains and five lift stations. The flows are pumped to the sewage treatment plant where the effluent is released to the Bow River. The total length of sewer lines within this study area is 17 200 m (VCT - 11 800 m; PVC - 5,400 m).

SERVICE POPULATION

The sewered area is divided into 11 service areas for which the land use data are presented in Table 1. Service areas 8 to 11 inclusive are outside the study area but have been identified because flow from these areas affects the facilities within the study area.

TABLE 1

Land Use Data for the Sewered Area

Service Area No.	Total Area Acres	Service Area Characteristics			
		Residential Area-acres	Commercial Area-acres	Institutional Area-acres	Industrial Area-acres
SA-1	113	83	15	15	-
SA-2	84	61	12	-	-
SA-3	89	81	-	-	-
SA-4	27	6	-	8	13
SA-5	67	22	30	-	9
SA-6	100	70	21	9	-
SA-7	34	34	-	-	-
SA-8	130	130	-	-	-
SA-9	20	20	-	-	-
SA-10	110	70	-	-	40
SA-11	1	-	-	-	-
Total	775	577	78	32	62

Table 2 summaries the present and future service population estimates. The residential population is calculated by assigning an average population density for the areas within the residential land use category. Service areas other than residential are assigned an equivalent service population based on unit sewage flowrates for those areas.

TABLE 2
Population Estimates for the Sewered Area

Service Area	Existing Population – Persons			Future Population Persons		
	Residential Population	Equivalent Population for Nonresidential Areas	Total Service Population	Residential Population	Equivalent Population for Nonresidential Areas	Total Service Population
SA-1	599	500	1,099	1,329	1,000	2,329
SA-2	565	200	765	948	400	1,348
SA-3	737	0	737	1,301	0	1,301
SA-4	48	70	118	96	350	446
SA-5	257	130	387	353	650	1,003
SA-6	553	633	1,186	1,120	1,267	2,387
SA-7	272	0	272	544	0	544
SA-8	390	0	390	2,080	0	2,080
SA-9	600	0	600	600	0	600
SA-10	490	1,333	1,823	1,120	2,667	3,787
SA-11	0	83	83	0	83	83
Total	4,511	2,950	7,461	9,491	6,417	15,908

SANITARY FLOWRATES

Sanitary flowrates were calculated using a per capita flow of 225 litres per capita per day (60 gpcd). Peak flowrates were determined by multiplying the average sanitary flow by an appropriate peaking factor.

INFILTRATION RATES

After analyzing previous wastewater flow records of the treatment plant and groundwater data obtained from Alberta Environment, we concluded the sewer system was subject to excessive groundwater infiltration. Inflow through manhole covers and from roof leaders is not considered to be a major contributor to extraneous sewer system flows.

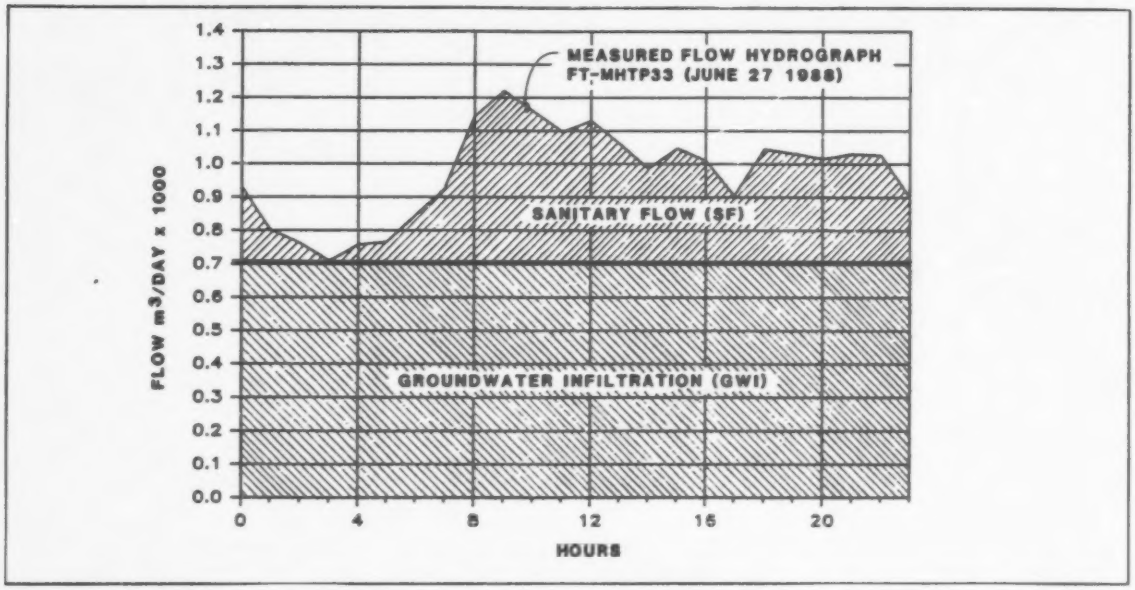
A wastewater flow measurement and groundwater monitoring program was undertaken from April to July 1987 to quantify the infiltration problem for various service areas within the sewer system. Flow measurements were taken at:

- Lift stations (4 No.)
- Sewage Treatment Plant
- Selected manholes in various service areas (using Marsh-McBirney, Model 260, Flo-Tote Flowmeter)

Groundwater was monitored in 12 existing wells. Two wells were continuously monitored using a Stevenson Type F level recorder.

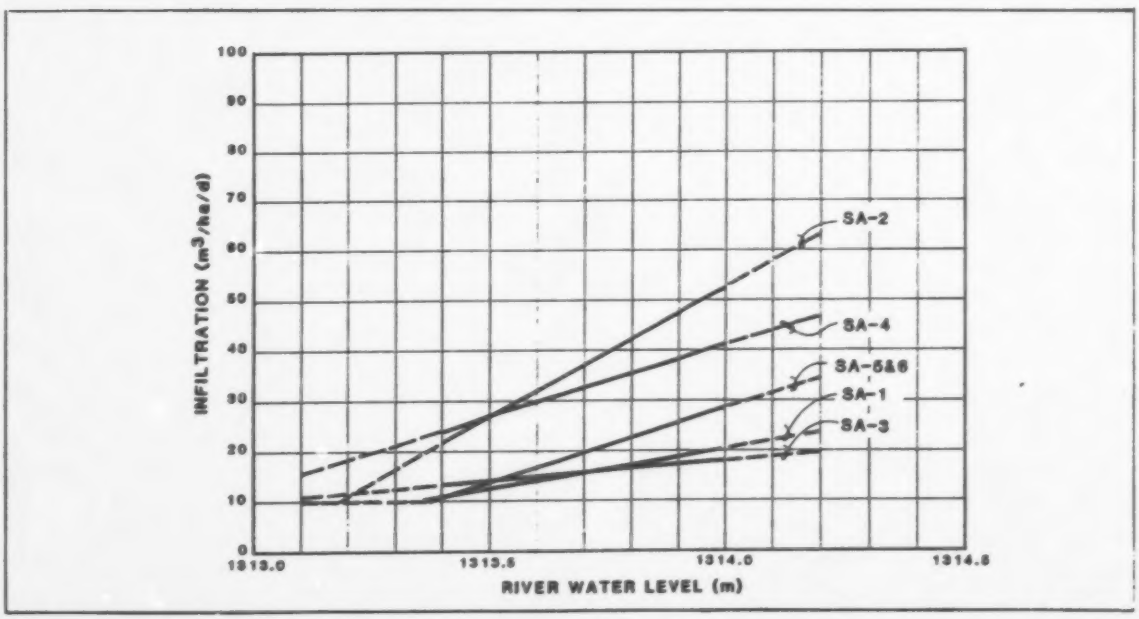
Figure 2 shows a flow hydrograph for June 27, 1988, at a manhole in the Tee Pee Town area. The extent of groundwater infiltration is significant.

FIGURE 2
Seperation of Sanitary Flow and Groundwater Infiltration



From the data collected during the measurement program, a correlation between infiltration rates and the river water level was possible. This correlation is shown in Figure 3.

FIGURE 3
Bow River Water Level vs Infiltration Rate
For Individual Service Areas
[See Figure TM3-1 for Service Area Locations]



Supplementary TV inspections were carried out where considered necessary. This information, together with actual flow measurements, was used to pinpoint all potential infiltration sources. Table 3 shows how this activity was detailed and reported.

TABLE 3

Potential Infiltration Sources

Sewer Run U/S MH	Sewer Run D/S MH	Service Area	Network	Infiltration gpm	Potential Infiltration Sources
I1	I2	SA-4	1	19.4	Pipe cracked and broken
I2	I3	SA-4	1	43.6	Pipe cracked and broken
	Total			63.0	
TP9	TP10	SA-6	2	13.5	4 out of 9 services running lengthy ponding
TP14	TP15	SA-6	2	2.8	3 out of 4 services running lengthy ponding
TP15	TP26	SA-6	2	13.7	1 out of 1 service running, local ponding
TP21	TP22	SA-6	2	22.6	4 out of 9 services running lengthy ponding
TP25	TP26	SA-6	2	7.8	1 out of 1 service running, lengthy ponding
TP27	TP28	SA-6	2	19.5	lengthy ponding
TP29A	TP29	SA-6	2	0	No TV inspection tape available
TP31	TP32	SA-6	2	5.2	No TV inspection tape available
TP32	TP33	SA-6	2	11.7	No TV inspection tape available
TP36	RR21	SA06	2	54.8	No TV inspection tape available
	Total			151.6	
9C	8H	SA-1A	3	19.5	No TV inspection tape available
8C	8D	SA-1A	3	15.9	Lengthy ponding
8D	8E	SA-1A	3	15.0	No TV inspection tape available
8E	8F	SA-1A	3	23.0	No TV inspection tape available
8G	8H	SA-1A		12.2	Infiltration at MH-8H
8I	8H	SA-1A	3	109.3	No TV inspection tape available
7H	7F	SA-1A	3	23.5	Lengthy ponding
5F	5H	SA-1A	3	39.8	Lengthy ponding infiltrat @ MH-5F & MH-5H
	Total			267.0	
4J	4I	SA-1B	5	19.8	No TV inspection tape available
4G	5H	SA-1B	5	13.5	No TV inspection tape available
	Total			33.3	

Table 4 shows a summary of design wastewater flows at the sewage treatment plant. Contributions from sanitary flows and infiltration are separated. The relative magnitudes indicate the severity of the infiltration problem.

TABLE 4

Summary of Design Wastewater Flows
at Sewage Treatment Plant

	Design Wastewater Flow - gpd x 1000			
	River Level @ 1314,0 m		River Level at 1314,5 m[1]	
	Average	Peak	Average	Peak
Present				
o Sanitary	538	1,810	538	1,810
o Infiltration	1,672	1,672	2,302	2,302
Total	2,210	3,482	2,840	4,112
Future				
o Sanitary	1,044	3,443	1,044	3,443
o Infiltration	1,672	1,672	2,302	2,302
Total	2,716	5,115	3,346	5,745

Notes:
(1) Used as the design basis for sewer system capacity analysis.

CAPACITY ANALYSIS

The hydraulic capacity of the sewer lines and the lift stations is of pivotal importance for the I/I study. The hydraulic capacity of the sewer lines was calculated using Manning's formula, assuming a roughness of 0.013. Sewer lengths were taken from as-built drawings. Invert elevations had to be field surveyed because the as-builts could not be relied on.

Hydraulic characteristics of all the lift stations were determined by means of a combination of field measurements and calculated rates.

ALTERNATIVE UPGRADING PLANS AND COST-EFFECTIVENESS ANALYSIS

Our analysis showed that infiltration constitutes a substantial fraction of the existing and future wastewater flows. It also showed that the existing flows can exceed the hydraulic capacities of the sewer mains during the summer months. The sewer system, therefore, needs to be either rehabilitated to reduce the infiltration entering the system or upgraded to provide additional hydraulic carrying capacity.

The decision to rehabilitate or to replace the sewers depends on the ability to find and repair infiltration sources and the comparative costs of rehabilitated and replaced systems. A major consideration in this type of study is usually the capacity at the treatment plant.

INFILTRATION/REDUCTION PLANS

Two development scenarios were considered in the study:

- Alternative 1 - Present Development
- Alternative 2 - Future Development

For each alternative, two levels of infiltration reduction were assessed and costed. The first level entailed removing the worst infiltration sources that could be corrected cost-effectively. The second, Level 2, assumed the more difficult sources are corrected at a higher relative cost. We also examined the option to totally replace sewers and service connections, which was considered to be an upper limit 100 percent removal of infiltration.

Table 5 presents a summary of wastewater flows at the treatment plant for alternative infiltration reduction schemes. Table 6 shows a typical tabulation of the rehabilitation works associated with the I/I reduction levels.

TABLE 5

Summary of Wastewater Flow for Alternative Infiltration Reduction Schemes

Alternative	Wastewater Flow @ River Level 1314.5 m gpd x 1000 Average	Peak
1. Present		
a. No infiltration reduction	2,840	4,112
b. Level 1 rehabilitation plan	1,970	3,242
c. Level 2 rehabilitation plan	1,792	3,064
2. Future		
a. No infiltration reduction	3,346	5,745
b. Level 1 rehabilitation plan	2,476	4,875
c. Level 2 rehabilitation plan	2,298	4,697
d. Replace sewers and service connections in service areas 1 through 6	1,401	3,944

COST ESTIMATES

Cost estimates for the construction of new facilities and rehabilitation of existing facilities were prepared for all levels of I/I reduction for both alternatives. These costs are presented in Table 7. All lift station wetwells are of adequate size to handle current and future flows. Lift station upgrading costs, therefore, include only mechanical and electrical components. Wastewater treatment plant costs are based on offline storage to handle flows above the current plant design capacity of 3.2 mgd.

Figure 4 shows a plot of infiltration reduction versus cost of transporting and treating the wastewater for future development conditions. It is apparent from this figure that the rehabilitation option and optimum level of infiltration reduction is approximately 1.0 mgd.

TABLE 8

Summary of Sewer Rehabilitation/Upgrading Works

Alternative 1

SEWER RUN U/S MH	SEWER RUN D/S MH	EXIST DIA	NETWORK	ALTERNATIVE 1a NO I/I REDUCTION: SEWER LINE REPLACE SEWER	SEWER LINE INSITU FORM	SEWER LINE GROUT JOINTS	MANHOLES REPLACE MH'S	MANHOLES FIBREGL LINER	SERVICE CONNS REPLACE	ALTERNATIVE 1b LEVEL 1 I/I REDUCTION: SEWER LINE REPLACE SEWER	SEWER LINE INSITU FORM	SEWER LINE GROUT JOINTS	MANHOLES REPLACE MH'S	MANHOLES FIBREGL LINER	SERVICE CONNS REPLACE	ALTERNATIVE 1c LEVEL 2 I/I REDUCTION: SEWER LINE REPLACE SEWER	SEWER LINE INSITU FORM	SEWER LINE GROUT JOINTS	MANHOLES REPLACE MH'S	MANHOLES FIBREGL LINER	SERVICE CONNS REPLACE	COMMENTS
I1	I2	8"	1							8"			2			8"			2			
I2	I3	8"	1							8"			1			8"			1			
TP9	TP10	8"	2												4		1				4	
TP14	TP15	8"	2	10"			1			10"			1		1	10"					1	
TP15	TP26	8"	2	10"			1			10"			1		1		1				1	
TP21	TP22	8"	2												4		1				4	
TP25	TP26	8"	2												1		1				1	
TP27	TP28	10"	2	12"			1			12"			1		2	12"			2		2	
TP29A	TP29	10"	2	12"			1			12"			1		2	12"			1		2	
TP31	TP32	10"	2	12"			1			12"			1		3	12"			1		3	
TP32	TP33	10"	2	12"			1			12"			1			12"			1			
TP33	TP36	10"	2	12"			1			12"			1			12"			1			
TP36	RR21	10"	2	12"			1			12"			1			12"			1			
TP11	TP12	8"	2	10"			2			10"			2									
TP12	TP13	8"	2	10"			1			10"			1									
TP13	TP14	8"	2	10"			1			10"			1									
TP26	TP27	10"	2	12"			1			12"			2			12"			1			
TP28	TP29A	10"	2	12"			1			12"			1			12"			1			
TP29	TP30	10"	2	12"			1			12"			1			12"			1			
TP30	TP31	10"	2	12"			1			12"			1			12"			1			
8C	8D	8"	3								1						1					
8D	8E	10"	3								1						1					
101	9C	12"	3	14"			2															
81	8W	12"	3								1						1					
7E	7F	12"	3	18"			1			16"			1			16"			1			
7H	7F	8"	3								1						1					
5F	5H	12"	3	18"			1			16"			1			16"			1			
9C	8H	12"	3	18"			1			16"			2			16"			2			
8W	7E	12"	3	18"			1			16"			1			16"			1			
7F	7G	12"	3	18"			1			16"			1			16"			1			
7G	5D	12"	3	18"			1			16"			1			16"			1			
5D	5E	12"	3	18"			1			16"			1			16"			1			
5E	5F	12"	3	18"			1			16"			1			16"			1			
10E	10F	12"	4								1						1					
10H	101	12"	4	16"			1			14"			1			14"			1			
10F	10G	12"	4								1						1					
10G	10H	12"	4	16"			1			14"			1			14"			1			
4J	4I	8"	5								1						1				2	
4G	5H	8"	5														1					
L33	L34	8"	6	12"			2			12"			2			12"			2			
RR12	RR13	10"	7												3						3	
RR14	RR15	10"	7												3		1				3	
RR15	RR16	10"	7												2						2	
RR17	RR18	10"	7												3						3	
RR19	RR20	10"	7												1						1	
16G	15H	12"	9							12"			2			12"			2			
15H	15I	12"	9							12"			1			12"			1			
14G	13H	12"	9							12"			2			12"			2			
13E	13G	12"	9							12"			2			12"			2			
12G	11G	12"	9							12"			2			12"			2			
11G	10G	12"	9							12"			1			12"			1			

TABLE 7
Cost Estimate Summary

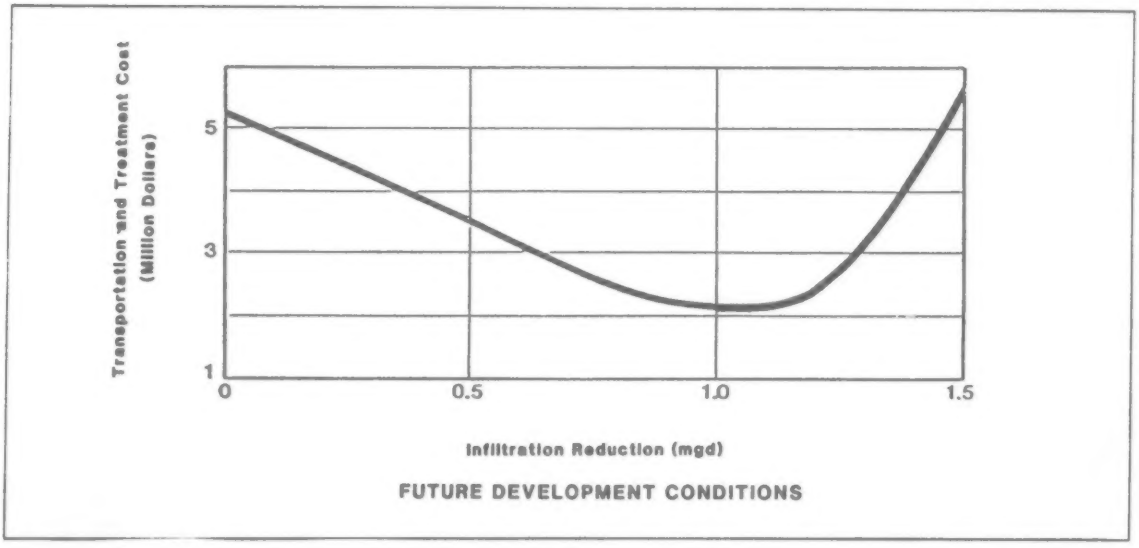
Alternatives	Estimated Cost[1] - $ x 1,000 Sewer Mains	Lift Stations	Treatment Plant	Total
1. Present Wastewater Flows				
(a) No infiltration reduction	1,030	112	350	1,492
(b) Level 1 rehabilitation plan	1,314	44	0	1,358
(c) Level 2 rehabilitation plan	1,461	44	0	1,505
2. Future Wastewater Flows				
(a) No infiltration reduction	1,158	131	3,900	5,189
(b) Level 1 rehabilitation plan	1,625	115	400	2,140
(c) Level 2 rehabilitation plan	1,623	113	350	2,086
(d) Replace sanitary sewer system	10,060[2]	-	400	10,460

Notes:

1. Estimated costs are in 1987 December dollars and do not include contingency, engineering, or administrative costs.
2. Cost for sewer replacement is $7,340,000; cost for service connection replacement is $2,720,000.

FIGURE 4

Infiltration Reduction vs. Cost



IMPLEMENTATION PLAN

The cost-effectiveness analysis showed that a program based on Level 1 reduction provided the most cost-effective option under future development conditions.

CH2M Hill developed an implementation plan for the capital improvements corresponding to this alternative. Since the town intends to carry out these improvements over a period of at least 3 years, we itemized, costed and prioritized the components of the program. Highest priority was given to the program components that provided the greatest reduction in infiltration and/or produced the most necessary increase in capacity. Table 8 shows the itemized upgrading program with its costs and priorities.

TABLE 8

Construction Cost Estimate with Implementation Priority

Area	Description	Quantity	Units	Construction Cost ($ x 1000)	Priority
Indust. Place	Replace sewer mains	400 (120)	ft (m)	55	1
Tee Pee Town	Replace sewer mains	4315 (1315)	ft (m)	600	2
	Replace service connections	18	#	110	2
Downtown	Replace sewer mains	2260 (690)	ft (m)	315	1
	Insituform sewer mains	1590 (485)	ft (m)	130	1
Downtown	Replace sewer mains	565 (170)	ft (m)	80	1
	Insituform sewer mains	570 (175)	ft (m)	50	3
Downtown	Insituform sewer mains	460 (140)	ft (m)	40	4
	Replace service connections	2	#	10	4
Larch	Replace sewer mains	125 (40)	ft (m)	20	4
Railway Ave.	Replace service connections	12	#	75	2
Downtown	Insituform sewer mains	1610 (490)	ft (m)	130	3
	Upgrade Lift Station No. 1	1	LS	50	1
	Offline storage at treatment plant	1	LS	400	3

DENITRIFICATION IN A WASTE STABILIZATION POND

A.B. Sparling and J.K. Stibbard
Department of Civil Engineering
University of Manitoba

INTRODUCTION

In June of 1985, Environment Canada sponsored a workshop in Winnipeg entitled "Cold Climate Sewage Lagoons". This conference was attended by representatives from governments, consultants and universities from across Canada.

At the end of this conference, one of the questions that did not appear to have a complete answer was the extent to which nitrogen removal occurred in conventional facultative sewage lagoons. This naturally includes nitrification and denitrification. The main unanswered question appeared to be, does denitrification occur in a waste stabilization pond or lagoon, and if so, to what extent?

This paper reports on an investigation which encompassed a literature review, laboratory studies and a field study designed to answer this question.

The site chosen to conduct the field study was primary cell number 2 at the West End Pollution Control Centre in the City of Winnipeg. These lagoons were constructed in 1964.

Cell Number 2 is an 18.2 hectare (45 acre) cell which receives raw sewage from the western part of the city. The cell has a nominal water depth of 1.5 m (5 feet). The sewage is basically of domestic origin.

LITERATURE REVIEW

Various researchers have studied denitrification in lakes and estuaries with emphasis on nitrogen transformations occurring in benthic sediments.

Goering (1) incubated lake sediments with isotopically labelled nitrate and collected labelled nitrogen gas, thereby determining that denitrification was occurring in the sediments.

Richards (2) used nitrogen-argon differential measurements to show that denitrification was occurring in anoxic zones in seawater. He examined chemical pathways for conversion of organic nitrogen to nitrogen gas and found this reaction was not possible.

Chen et al (3) examined nitrification and denitrification in sediments. By adding selective bacterial inhibitors, they stopped the reactions, thereby showing that both reactions were biologically mediated.

Kuznetsov (4) analyzed gases collected from lake and reservoir sediments and found compositions ranging from 11 to 29 percent nitrogen, 63 to 80 percent methane and the remainder hydrogen and carbon dioxide.

Chen et al (5) collected gases in situ from lake sediments and found 24 to 50 percent nitrogen and 45 to 75 percent methane. Use of labelled nitrogen tracing subsequently proved biological denitrification was occurring.

Kaplan et al (6) measured denitrification in salt marshes and found a linear relationship between temperature and rate of nitrogen gas production. They also found that separate mesophilic and psychrophilic populations of denitrifiers were active at different temperatures with approximately 11^{0}C being the cross over temperature between populations.

The literature reviewed indicates clearly that biological denitrification readily occurs in lake and marsh sediments but no reports could be found of comparable research performed on wastewater lagoon sediments.

EXPERIMENTAL PROCEDURE

Gas collection apparatus was placed in cell number 2 in June of 1986. The apparatus consisted of two floating and one benthic collector. The benthic collector was placed adjacent to one of the floating collectors. Figure 1 shows the locations of the collectors. Figure 2 shows how the surface and benthic collectors were installed.

FIGURE 1
City of Winnipeg WEPCC #2 Primary Cell with Locations of gas sample collectors. Scale 1:3333 (metric)

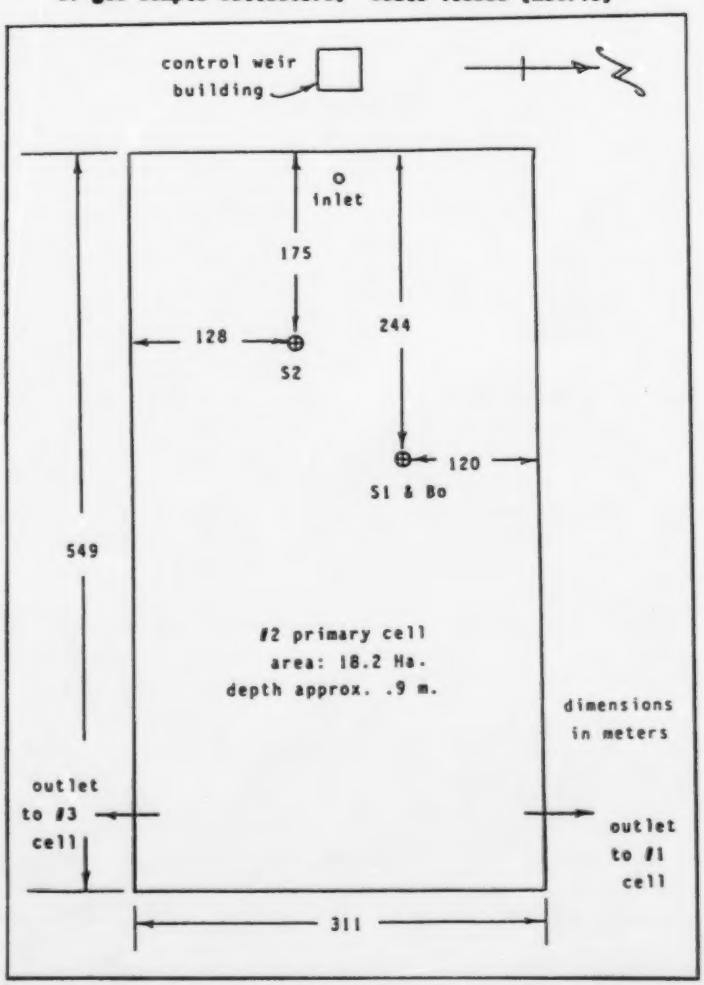
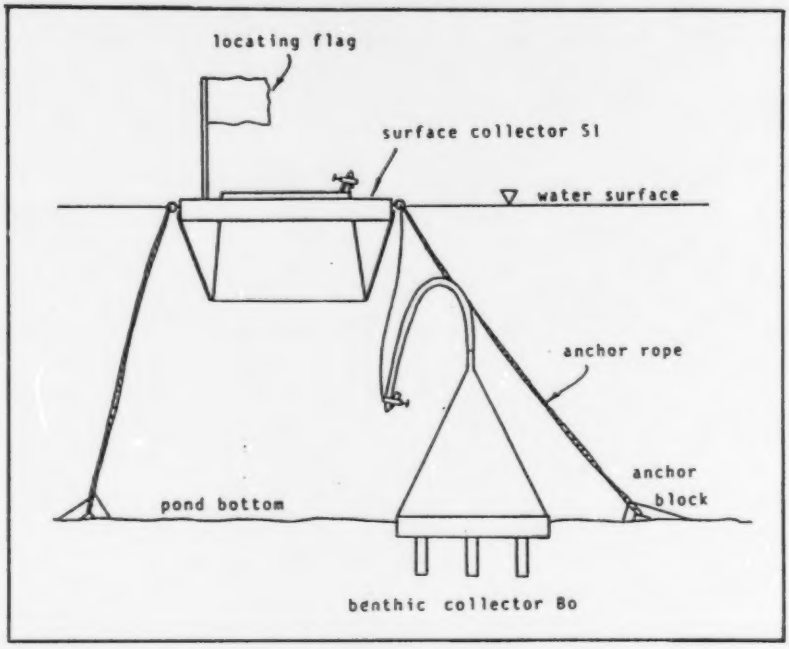


FIGURE 2
Surface and benthic gas collecting apparatus as arranged in #2 pond (not to scale)



A Nalgene 6130 hand vacuum pump was used to evacuate all the air from the gas collectors. Rising gases evolved in the water or benthic deposits of the lagoon were then trapped under the collectors. Gas sampling apparatus, consisting of the hand vacuum pump and Fisher 134-190 septum port gas sampling tubes, was used to remove accumulated gas without contamination by air.

The sampling program began with removal of gas samples from the collectors on September 8, 1986 and continued with the removal of samples approximately once per week for 8 weeks until October 30 when freeze up terminated the field study. Surface and bottom water temperatures were recorded at the time gas samples were collected. Water samples were also taken for pH, dissolved oxygen, ammonia and nitrate determinations.

LABORATORY PROCEDURES

Collected gas samples were analyzed for nitrogen, methane, oxygen and carbon dioxide using a Gow Mac 550 Thermal Conductivity Gas Chromatograph. Nitrogen, oxygen and methane were measured using SA 60/80 mesh molecular sieve, carbon dioxide was measured with Poropak Q 80/100 mesh. Calibration and use of the gas chromatograph was as detailed in Standard Methods for the Examination of Water and Wastewater, 16th Edition, 1985, method 511B. A Tecator Kjeltic System 1002 distilling unit and a Bausch and Lomb Spectronic 20 spectrophotometer were used for ammonia analysis, Standards Methods sections 417A and 427B. Nitrate was analyzed using a Scientific Instrument Corporation, auto analyzer following Standard Method 418F. pH was determined using a Fisher Accumet 230 pH/ion meter. Dissolved oxygen was measured by Standard Method 421B, azide modification.

EXPERIMENTAL DATA AND RESULTS

The nine weeks over which the field study was conducted are numbered sampling periods 1 through 9. The surface sampler adjacent to the benthic collector is called S1, the other surface sampler is called S2. The benthic sampler is called Bo. Results of composition of the gases collected in the samplers are given in Table 1. Results of the water analysis are given in Table 2.

TABLE 1
Gas Composition Analysis - 3 samplers, Cell 2, WESPCC
September - October 1986

		S1 Gas Analysis %				S2 Gas Analysis %				Bo Gas Analysis %			
Period	Date	N_2	CH_4	O_2	Total	N_2	CH_4	O_2	Total	N_2	CH_4	O_2	Total
1	Sept 8	80	0	14	94	93	4	4	101	72	7	17	96
2	Sept 11	85	T	8	93	80	0	17	97	26	76	T	102
3	Sept 17	95	1	4	100	83	2	12	97	23	73	1	97
4	Sept 26	92	T	4	96	83	12	4	99	24	68	4	96
5	Oct 1	68	30	2	100	insufficient sample				15	82	1	98
6	Oct 8	insufficient sample				82	1.5	15	98.5	27	73	1.5	101.5
7	Oct 16	84	T	16	100	insufficient sample				22	79	1	102
8	Oct 22	82	1	16	99	insufficient sample				19	74	.5	93.5
9	Oct 30	63	3	19	85	79	2	19	100	32	67	2.5	101.5

TABLE 2
Results of wet analyses, Cell 2, WESPCC
September - October, 1986

		Water Temp. 0^oC		Dissolves O_2 mg/l		NH_3 mg/l		NH_3 mg/l		
Period	Date	Surface	Bottom	Surface	Bottom	SI	Outfill	SI	Outfill	pH
-	Sept 4	15	15	1.5	2.3	20.8	-	.06	-	7.2
1	Sept 8	13	12	2.8	1.2	20.0	-	.10	-	7.4
2	Sept 11	16	14	4.4	.1	21.6	-	.08	-	7.2
3	Sept 17	11	11	.2	0	21.6	-	.07	-	7.5
4	Sept 26	15	15	.9	.9	24.6	-	.05	-	7.3
5	Oct 1	12	12	0	.2	24.8	22.5	trace	.05	7.6
6	Oct 8	7	7	1.6	1.5	25.6	23.6	.05	.06	7.8
7	Oct 16	5	5	3.9	2.9	31.2	28.4	.08	.08	7.7
8	Oct 22	10	10	3.1	2.8	28.8	27.2	.08	.06	7.8
9	Oct 30	1	1	4.9	4.2	26.4	22.4	.06	.06	7.7

An attempt was made to calculate the yield of nitrogen gas from the benthic deposits on a unit area basis. Volumes of nitrogen gas expected to be liberated from solution due to changes in temperature and atmospheric pressure over each sampling period were calculated and subtracted from the volumes of nitrogen collected. In all cases the volume of nitrogen collected was greater that the volume expected to be liberated due to temperature and pressure change. The differences were corrected to $0^{o}C$ celsius and divided by the number of days in the sampling period and the area of the pond bottom covered by the samplers to obtain a volume of nitrogen gas evolved as milliliters per day per square meter of bottom area. The unit nitrogen production so calculated for each sampling period and sampler are given in Table 3, and plotted vs median water temperature in Figure 3. A straight line was fitted to the data points in Figure 3 by least square analysis and a correlation coefficient of .56 determined. For 26 data points, a correlation coefficient of at least .42 is required for statistical validity, therefore it can be seen that a statistically valid relationship does exist between nitrogen gas collected and lagoon water temperature for this data.

The equation of the data points in Figure 1 is given in equation I

$$U = 6.9T + 1.5 \quad \text{..... I}$$

where: U = nitrogen gas production milliliters per square meter per day

T = temperature - degrees Celsius

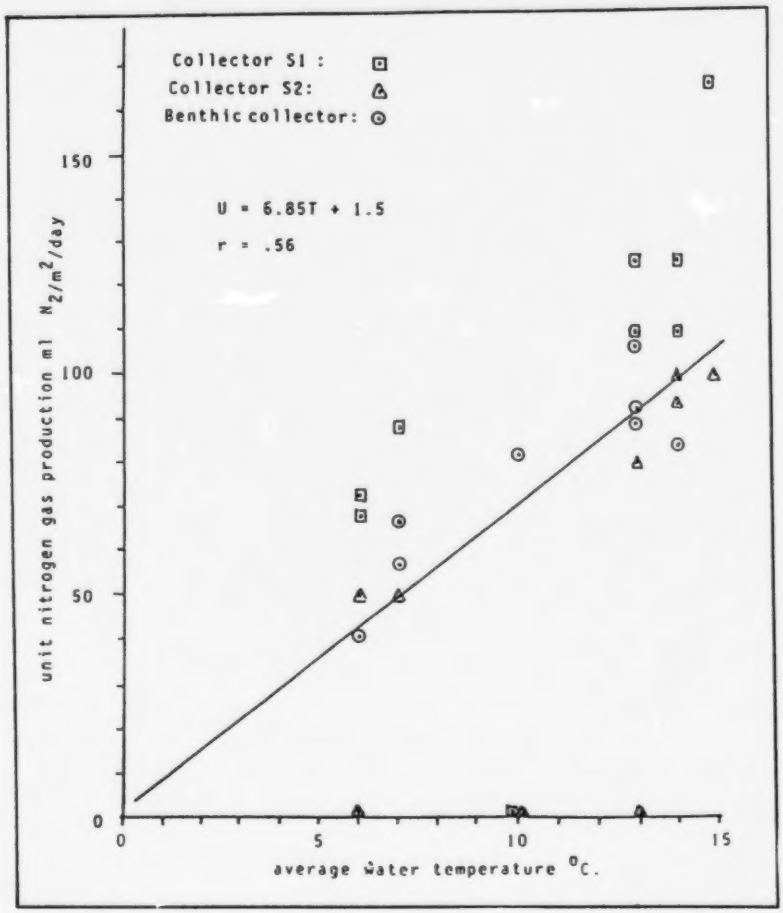
TABLE 3

Volume and Unit Nitrogen Gas Production, 3 samplers, Cell 2 WBMPCC
September - October 1966

Period	Days in Period	Water Temp ^{o}C	S1		S2		Bo	
			N_2 Collected mls (to $0^{o}C$)	Unit N_2 Product. mls/m^2/d	N_2 Collected mls (to $0^{o}C$)	Unit N_2 Product. mls/m^2/d	N_2 Collected mls (to $0^{o}C$)	N_2 Product mls/m^2/d
1	4	14	53	127	38	93	-	-
2	3	15	50	167	28	98	19	92
3	7	13	90	127	56	78	43	87
4	9	13	101	110	0	0	67	106
5	5	14	54	110	50	98	29	82
6	7	10	0	0	0	0	40	81
7	7	6	56	68	0	0	22	40
8	6	7	56	88	31	49	26	56
9	8	6	58	71	41	49	31	56

FIGURE 3

Unit nitrogen gas production versus average pond water temperature



Nitrogen gas production and surface and bottom water temperatures are plotted in Figure 4. It can be seen from Figure 4A that the median water temperature fell from 13 to 15° to between 6 and 7° from October 1 to October 16. Figure 4B shows a significant drop in nitrogen gas production, particularly in the surface collectors during this period. The drop in nitrogen production is also evident in the data points in Figure 3. This reduction in nitrogen production in the temperature range of 12° to 7° is considered to be due to a change in activity from mesophilic to psycrophilic denitrifiers.

FIGURE 4

Unit nitrogen gas production and temperature versus time

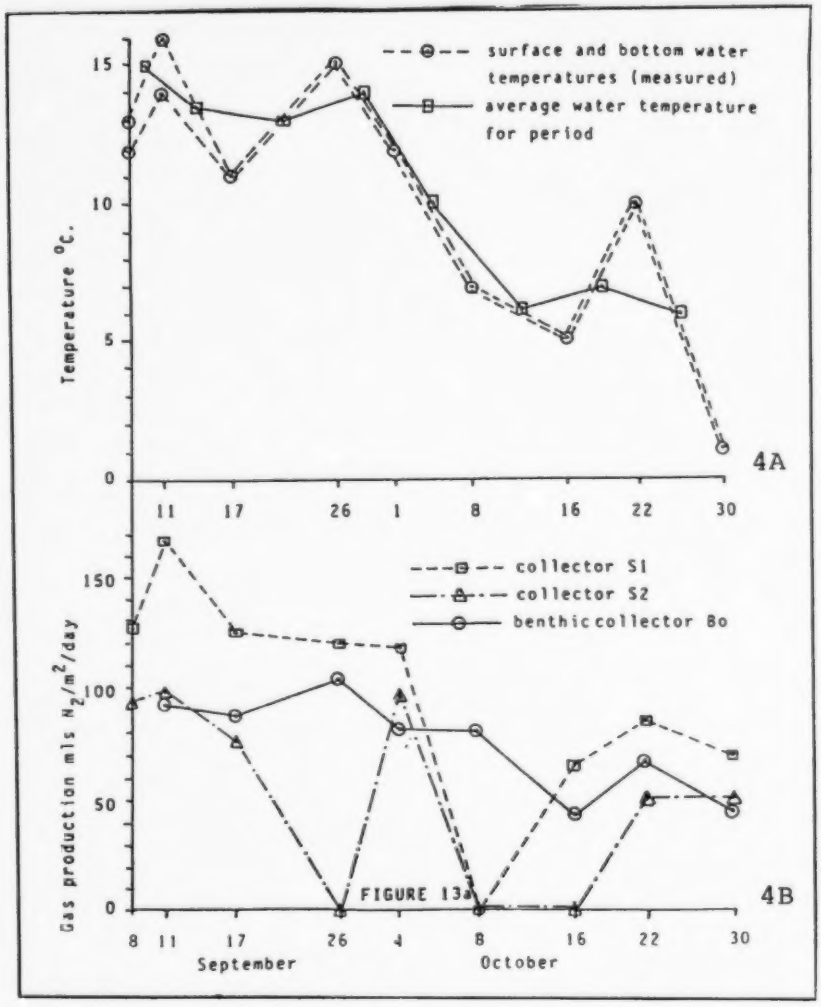


FIGURE 13a

NITROGEN BALANCE

An attempt was made to determine the effect of the experimental findings upon the nitrogen balance in the lagoon. Average influent and effluent ammonia levels in the pond over the test period were 27.9 mg/L and 24.8 mg/L respectively, giving a reduction of 3.1 mg/L through the pond. Multiplying this by the average daily flow gives a mass loss of 23.6 kg of ammonia per day. From Figure 3, the rate of nitrogen gas production at the average pond temperature of

8.5°C was 60 mls per square metre per day. Converting this gas volume to a mass of ammonia and multiplying by the total pond area of 170,000 square meters gives a mass loss of approximately 15.1 kgs of ammonia per day. Ammonia may also be lost from water by volatilization of ammonia gas and this volatilization can be calculated if temperature and pH are known. Using these parameters, a mass loss of ammonia due to volatilization of 10.6 kgs per day was calculated. This gives an estimated total ammonia loss of 25.7 kgs. per day, which is close to the 23.6 kg per day measured difference between the influent and effluent ammonia. While the calculations come close to balancing the ammonia in the pond, the result must be interpreted with caution due to a number of variables which could not be factored into the calculation. Some of these are:

- organic nitrogen in the influent which would provide an additional source of ammonia.
- quantities of nitrogen in various forms accumulated in the pond sediment which could be mobilized at rates which cannot be accounted for in the above calculation.
- ammonia may be excreted as well as utilized by certain micro organisms.

CONCLUSIONS

There is strong evidence that nitrogen gas was being evolved from the pond in significant excess of that expected due to changes in temperature and pressure. While it would seem most probably that this nitrogen was the result of biological denitrification, this cannot be stated conclusively solely from the results of this study.

The volume of nitrogen gas evolved bears a statistically valid relationship to the temperature of the lagoon water.

The fact that the volume of nitrogen gas collected in the three collectors were within the same order of magnitude on a unit bottom area basis and not on a volume of water under the collector basis would indicate that the benthic sediment was the source of the excess nitrogen collected.

It would appear that, while quantities of nitrogen gas may be lost from a lagoon due to denitrification, the denitrification process does not constitute a significant pathway of nitrogen removal. This is probably due to the limited amount of nitrification of ammonia which occurs in a facultative pond. Since nitrate does not accumulate in significant quantities in lagoons, and the denitrification reaction is relatively rapid under anoxic conditions if nitrate is available, it would seem reasonable to conclude that nitrification of ammonia is the rate limiting step preventing significant overall removal of nitrogen in facultative waste water lagoons.

ACKNOWLEDGEMENT

The assistance of the City of Winnipeg Waterworks, Waste and Disposal Department in providing information and access to facilities for this project is sincerely appreciated.

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APPENDIX A

Appendix A includes those papers for which the authors were not able to provide complete text.

Presentation outlines and/or figures which are felt to be of benefit to the reader have been included.

If the reader wishes more specific information, it is recommended that the speaker be contacted directly.

A 'RISK ASSESSMENT' APPROACH TO EVALUATING BENEFITS OF EFFLUENT DISINFECTION

J.M. McKernan, M.Sc.
Branch Manager
MacLaren Plansearch Inc.
Winnipeg MB

G. Rempel, P.Eng.*
Special Projects Engineer
Wardrop Engineering Inc.
*formerly Vice President, MacLaren Engineers Inc.

INTRODUCTION

"Reappraising Effluent Disinfection"

- Key Environmental Engineering Challenges in the 1990's
  - best use of various technologies
  - wisest use of public funds
  - environmental protection viz. 'sustainable development'
- Disinfection of North American Wastewater Effluents is Typical
  - "If Technology Available, its application is a social benefit
- Focus is protection of human health viz. various water uses.
- Policy and practices of wastewater disinfection currently under review.
  - construction, operation and expensive
  - municipal budgets under increasing pressure
  - disinfection will not eliminate disease-causing agents
  - harmful by-products may be formed
  - impaired water quality causing loss of aquatic habitats and biota
  - heightened public and municipal consciousness re: hazardous chemicals
  - is universal application appropriate?

Need for Estimation of Disinfection Benefits

- "Disinfection not favored in Western Europe" (Canada EPS 1978)
- Many pathogenic viruses resistant to disinfection (Butler 1981); selective resistance to chlorine can be "cultivated" in viruses (Bates et. al. 1977)
- "Selective disinfection of municipal effluents can be supported ... no room in prudent public policy for mandatory universal chlorination" (Chicago 1984)
- Water quality standards "should have an epidemiological basis for relating risk to health protection" (Schertzer 1986)

- "True value of disinfection uncertain" (Wisconsin 1985)

Benefits from Effluent Disinfection

- Improved compliance with water quality objectives?
- Reduced human health risk from water uses?
  - domestic consumption
  - primary recreation
  - secondary recreation
  - irrigation
- Benefits must be quantified (i.e. measurable) to attract support
- Greatest challenge relates to reduced health risk:
  - how to quantify?
  - how much benefit?
- Methodology innovation required to respond to the challenge

Decision Making Requirements

- Determine site-specific impacts of effluent (and other) discharges on water quality.
- Determine types and amounts of water use
- Evaluate relative abilities of disinfection methods
- Relate improved water quality to reduced risk of water use
- The specific technical challenge
  - develop better methods/analytical approaches to benefit/cost evaluation to aid assessment of the <u>need</u> for disinfection
  - be able to demonstrate the benefits of a disinfection policy

Background to Local Study

- In Winnipeg 3 wastewater treatment plants discharging to Red and Assiniboine Rivers
- Effluents not presently disinfected
- Concern for microbial quality of Red and Assiniboine Rivers expressed by City of Winnipeg and Province of Manitoba
- Province has proposed water quality objectives intended to reduce health risk associated with river uses.

- Objectives for microbial concentrations presently exceeded in Red and Assiniboine Rivers in the Winnipeg area and downstream

- Clean Environment Commission recommended disinfection of wastewater effluent in Winnipeg (1981)

- Citing other reviews and municipal decisions, Winnipeg has expressed doubt as to benefits

- Following outlines a general approach useful for others

  - considering whether to disinfect
  - reconsidering previous commitments to disinfect

EPIDEMIOLOGY

- Science relating pathogenic exposures to disease incidence

- Based on

  - "robust" research design
  - control of confounding influences
  - large number of environmental samples
  - large numbers of disease cases
  - retroactive statistical analyses

- costly

- time-consuming

- vulnerable to taxonomic imprecision

- can be powerful tool

- is link between "cause" and "effect" real?

HEALTH RISK ASSESSMENT

- quantitative risk assessment methods used

- based on recent Canadian and American Epidemiological studies

- empirical data related discrete water uses and quality to disease incidence

- predictive relationships derived from empirical data

  - salmonella spp.
  - E-coli
  - total fecal coliforms
  - total viruses

- disease incidence estimated under future ("disinfection") and ("no disinfection") scenarios

- general background information required in any study:

  - microbial loadings to river
  - microbial concentrations in river
  - river uses
    - type
    - amount
    - distribution

Background Data for Risk Assessment and Study

1. Microbial Loadings

   o Urban sources of microbial pollution require characterization

   A] Dry Weather Flows (DWF)
   B] Wet Weather Flows (WWF)

   o Only one source considered for disinfection

   A] Dry Weather Flows (Focus of Disinfection Options)

   - major source are wastewater treatment plants year-round
   - secondary treatment reduces microbial concentrations but still large quantities in effluent
   - C.O.W. has some microbial descriptive data

   B] Wet Weather Flows (not considered for disinfection)

   - major source is combined sewer overflows
   - seasonal (summer)
   - sporadic (about 30 times per year)
   - major contributions of microorganisms to river
   - microbial descriptive data can be poor; C.O.W. has useful data
   - river water quality studies require evaluation of both DWF and WWF qualities

2. Microbial Concentration in River (River Quality)

   o Combination of methods:

   - statistical analysis of existing stream data
   - mathematical computer-based simulation of river system
     - based on EPA model
     - "state-of-the-art"
     - accepted methodology
   - two approaches complementary

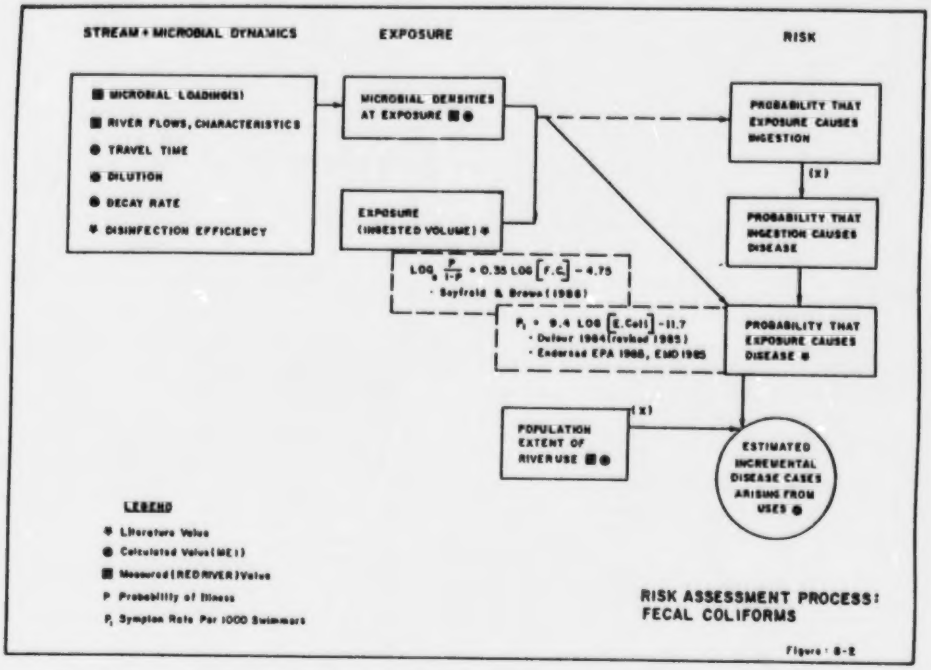
- Methods incorporate wide spectrum of local information:
  - local stream measurements of microorganisms
  - local discharge data (DWF and WWF)
  - hydrologic data
  - physical river data
  - literature review
  - professional judgement and experience
- Result
  - microorganism concentration profiles along the rivers
  - values along profile input to estimate river use risk at specific locations

Magnitude of Use

- Epidemiological relations require data on types, amount of use
- Focus on uses involving ingestion
  - drinking water
  - partial immersion
  - total immersion (swimming)

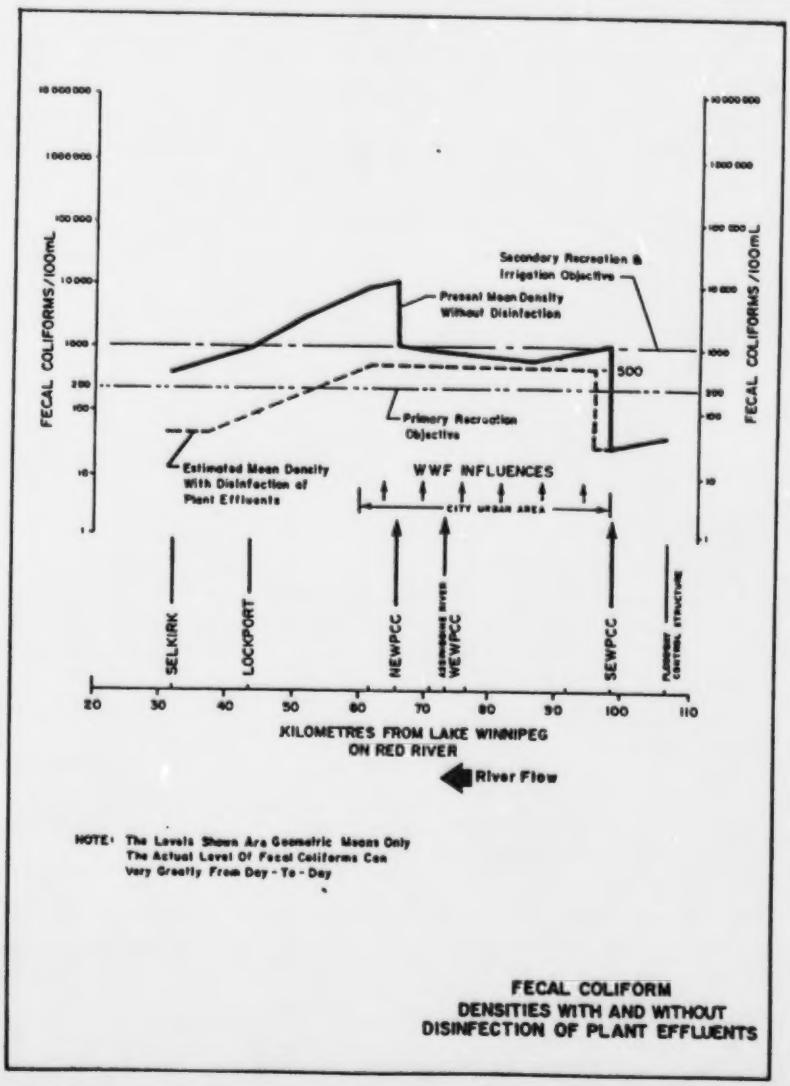
Table E-1
River Use and Immersion Events

1.	Primary Recreation		
	A. Swimming		
	10 People/d x 100 d/yr	=	1000 'events'
	or 500 people swim 2 x a year		
	B. Water-Skiing		
	60 people/d x 50 d/yr	=	3000 'events'
	Estimated Total Primary Recreation Each Year	=	4000 'events'
2.	Secondary Recreation		
	A. Boating		
	275 launches (commercial berths) x 4 people/boat	=	1,100 people
	12 launches (public) x 200 boats/launch x 4 people/boat	=	9,800 people
	B. Rowing		
	50 active (regular)	=	50 people
	C. Canoeing		
	500 active (but irregular)	=	500 people
	TOTAL PEOPLE	=	11,250 people
	Boating Immersion Frequency is 4.56% (Red Cross 1984)		
	Estimated Total Secondary Recreation Each Year	=	500 "events"



RISK ASSESSMENT PROCESS: FECAL COLIFORMS

Figure 8-2



NOTE: The Levels Shown Are Geometric Means Only The Actual Level Of Fecal Coliforms Can Vary Greatly From Day - To - Day

FECAL COLIFORM DENSITIES WITH AND WITHOUT DISINFECTION OF PLANT EFFLUENTS

Table E-3
Fecal Coliform Assessment Results - Canadian Study
Incremental G.I. Risk From Primary Recreation

WINNIPEG

PARAMETER	MEAN fc CONCENTRATIONS	EXTREME CONDITIONS
No Disinfection		
Indicator Density	1×10^3	1×10^4
Symptom Rate/1000	24	33
Immersion Events	4×10^3	4×10^3
Estimated Cases	100	132
With Disinfection		
Indicator Density	5×10^2	5×10^2
Symptom Rate/1000	22	22
Immersion Events	4×10^3	4×10^3
Estimated Cases	88	88
Avoided Cases	12	44

f.c. - fecal coliforms
G.I. - Gastrointestinal Disease

Table E-4
Fecal Coliform Assessment Results: American Study
Incremental G.I. Risk from Primary Recreation

SELKIRK

PARAMETER	MEAN f.c. CONCENTRATION	EXTREME CONDITIONS
No Disinfection		
Indicator Density	5×10^2	5×10^2
Symptom Rate/1000 (from equation)	14	23
Immersion Events	4×10^2	4×10^2
Estimated Cases	6	9
With Disinfection		
Indicator Density	1×10^2	1×10^2
Symptom Rate/1000 (from equation)	7	7
Immersion Events	4×10^2	4×10^2
Estimated Cases	3	3
Avoided Cases	3	6

f.c. - fecal coliforms
G.I. - Gastrointestinal Disease

Table E-7
Fecal Coliform Assessment Results: Canadian Study
Incremental G.I. Risk from Secondary Recreation

WINNIPEG PARAMETER	MEAN f.c. CONCENTRATIONS	EXTREME CONDITIONS
<u>No Disinfection</u>		
Indicator Density	1×10^3	1×10^4
Symptom Rate/1000	25	33
Immersion Events	5×10^2	5×10^2
Estimated Cases	13	18
<u>With Disinfection</u>		
Indicator Density	5×10^2	5×10^2
Symptom Rate/1000	22	22
Immersion Events	5×10^2	5×10^2
Estimated Cases	11	11
Avoided Cases	2	7

f.c. - fecal coliforms
G.I. - Gastrointestinal Disease

Table E-8
Summary of Results - Incremental Yearly
Gastrointestinal Risk from Recreation,
Based on An American Epidemiological Study (EPA 1986)

	WINNIPEG		SELKIRK	
	Mean <u>E. Coli</u> Concentration	Extreme Conditions	Mean <u>E. Coli</u> Concentration	Extreme Conditions
<u>Without Disinfection</u>				
Primary	64	104	6	9
Secondary	8	13	0 (<1)	1
TOTAL	72	117	6	10
<u>With Disinfection</u>				
Primary	56	56	3	3
Secondary	7	7	0 (<1)	0
TOTAL	63	63	3	3
(Primary and Secondary Avoided Cases)	9	54	3	7

Other Health Assessments

Drinking Water

- Selkirk - Supplemental, Discontinue Use
- Estimate 1 case of gastrointestinal illness (viral) in 35 years

Irrigation

- no disease incidence:
  - use too limited
  - irrigation objective met some to most of the time at present, downstream of Winnipeg
- estimated disease incidence from aerosols unmeasurable

OBSERVATIONS

- Typically, absolute microbial concentrations not most important in determining recreation-related case loads
  - typically, disease incidence will be use-driven
  - low number of cases due to low levels of primary recreation
- If greater primary recreation follows effluent disinfection, greater amounts of illness will result from the increased exposure
- Quantified relationship between microbial concentrations & health risks indicate that a risk is associated with recreational water use even when surface water quality objectives are met
  - for objective of 200 fecal coliforms/100 mL risk is at least 10 cases per 1000 swimmers
- Quantification of health risks raises questions of public value judgments and policy
  - is current risk level a problem?
  - how much reduction in risk is significant?
  - what river use(s) will benefit?
- There will be improved compliance with water quality objectives
  - province must decide if this is sufficient
- There will be reduced health risk for water users
  - city must decide if costs are commensurate with quantified benefit
- Certain uses can benefit
  - city must decide if promoting use(s) is justified, given prediction increase in disease
- Innovative, quantitative approach to benefits has highlighted policy issues more clearly

CONCLUSION

- Objective of study was to provide information to facilitate decision on the need/benefit to disinfect effluents
- City of Winnipeg study exemplifies quantitative approach helpful in other site-specific evaluations
- Risk assessment-oriented evaluation facilitates comparison of costs with use-related benefits
- Policy issues inevitably emerge from such an approach
- Quantification of health risk and disease cases an innovative approach
- Provides important biological and social perspective to an engineering study facing 1990's challenge of best use of technologies

ACKNOWLEDGEMENTS

- COW/Prov. Funding
  - Waterworks, Waste and Disposal Division
  - Municipal Affairs/Environment
- STUDY TEAM
  - R. Marr, M.Sc.
  - D. Morgan, Ph.D. (Pending)

EVALUATION OF MUNICIPAL SEWER USE CONTROL OPTIONS - PHASE II

EFFECTIVENESS - COST EVALUATION AND POLICY RECOMMENDATION

[Stopping Water Pollution at its Source]
[Municipal/Industrial Strategy for Abatement (MISA)]

presented by

Steve McMinn
M.M. Dillon Limited

EXECUTIVE SUMMARY

This report represents Phase II of a study of Municipal Sewer Use Control Options designed to identify a preferred program for Ontario which will control industrial discharges to sewers and the meet the goal of the MISA program.

The Phase I Report was submitted to the Ministry on September 16, 1987. It outlined the results of a survey of sewer use options being used in Canada, the United States, United Kingdom, France, West Germany and Japan. The programs in the various countries were described in detail, including information on technical, legislative, economic and administrative effectiveness aspects. Using a number of "exclusionary criteria", the programs from Canada, United Kingdom and Japan were excluded and of the existing programs only those from the United States, West Germany and France were selected for detailed evaluation. In addition, four hybrid programs were developed using existing programs and adding selected elements. Altogether, eight sewer use control options were included for detailed evaluation in Phase II.

For the sewer use control options studied, two fundamentally different types of standards were identified. Pretreatment Standards (PS) and Industrial Effluent Quality Standards (IEQS).

A Pretreatment Standard (PS) defines a permissible concentration or mass emission of contaminant per unit of production specific to an industrial category and based on Best Available Technology, Economically Achievable (BATEA).

The United States and French programs were shown to conform to the PS model.

An Industrial Effluent Quality Standard (IEQS) defines a permissible concentration and mass emission of a contaminant for industry in general.

The existing German program was found to conform to the IEQS model, although since 1986 Germany has been moving towards a PS type program.

While PS and IEQS were convenient and appropriate labels to define the various existing programs, it became inappropriate to use such absolute terms as we developed a preferred system

for Ontario which may have elements of both systems. Indeed, all the existing programs fell somewhat between the two definitions.

A number of unique descriptors were developed which allowed different programs (options) to be broken down into more simple elements for comparative purposes. The descriptors referred to the level of authority for regulation setting and enforcement, the nature of the legal system, and the fiscal aspects of sewer use controls.

The approach used to carry out the detailed evaluation of the options identified in Phase I was an effectiveness-cost approach. The effectiveness of a sewer use control option is a measure of how well the program:

. meet its goal of abating the discharge of pollutants from industrial outfalls into the municipal sewer system and;

. minimizes subsequent impacts on the environment.

The costs of an option are divided into monetary and social costs and are used only after the effectiveness ranking is complete, in effect to confirm (or modify) the ranking produced from effectiveness considerations.

The effectiveness of a sewer use control option was measured using four factors:

- technical effectiveness;
- economic effectiveness;
- legislative effectiveness;
- organizational and administrative effectiveness.

Each of the above factors was then sub-divided into a number of sub-factors. Detailed questionnaire responses from the various international jurisdictions were then related to the sub-factors. The collected data was then analyzed to identify strengths and weaknesses of the various options and their applicability to Ontario.

The evaluation of options then took place through a qualitative comparison of the eight options considered, by factor. From this comparison, a list of options was constructed, ordered (ranked) as to preference according to each of the factors: technical, economic, legislative, and, organizational and administrative effectiveness. A preferred option, based on overall program effectiveness, was then identified. Cost considerations were then applied and a modified ranking was developed.

The evaluation process identified a program based on the one now in place in the United States, with the addition of a formal incentive program for industrial compliance as the preferred option for Ontario. Broadly, this option is defined as follows:

- a categorical pre-treatment standard based on BATEA that also utilizes industrial effluent quality standards for industrial categories not specifically addressed;

- regulations set by the province with allowance for municipalities to set more stringent standards ("local limits") if desired, provided they can demonstrate a need based, for example, on local receiving water quality impact;

- regulations are enforced by the local or regional municipalities (with Provincial auditing) except in these cases where the local capability does not exist, in which case the Province takes over the role of enforcer;

- a fiscal incentive program is applied to encourage compliance and continued improvements in the effectiveness of the control program over time.

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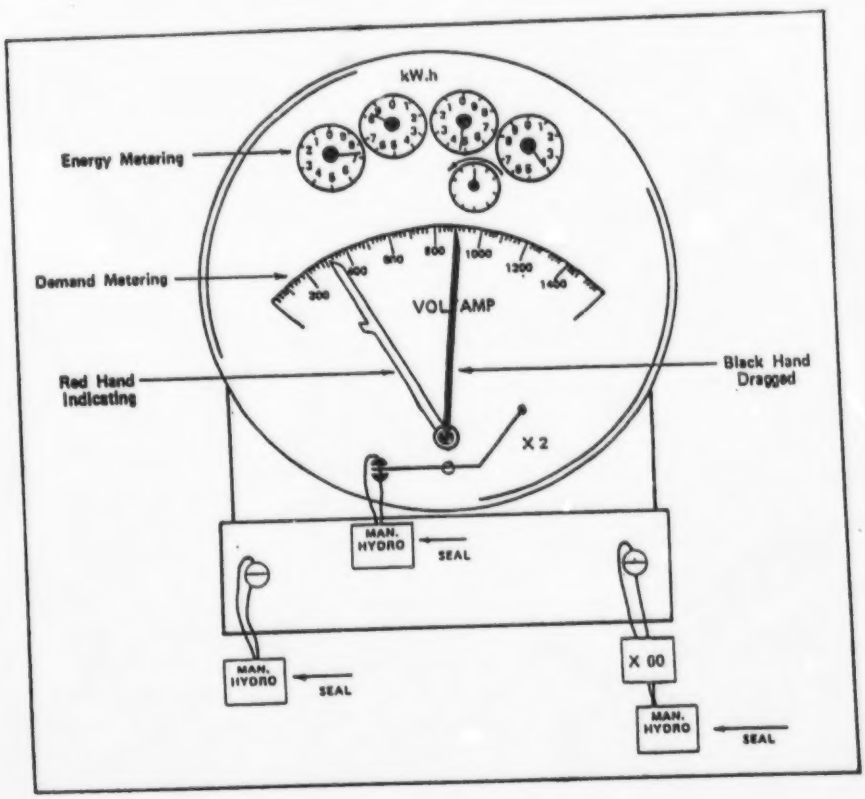
LOAD MANAGEMENTS AND ITS EFFECTS ON ELECTRICITY BILLS

G. Cyril Cartwright, P.Eng.
Manager, Rates Department
Manitoba Hydro
Box 815
Winnipeg MB
R3C 2P4

Factors affecting monthly electricity bill

- transformer ownership
- consolidation of services
- load shifting
- power factor
- demand ratchet

DEMAND-ENERGY METER



GENERAL SERVICE - LARGE
(Customer Owned Transformation)

	Exceeding 750 V to not exceeding 30 kV	Exceeding 30 kV to not exceeding 100 kV	Exceeding 100 kV
Energy Charge	1.691 ¢/kW.h	1.691 ¢/kW.h	1.691 ¢/kW.h
PLUS			
Demand Charge per kV.A of Monthly Billing Demand*	$6.15/kV.A	$5.53/kV.A	$5.02/kV.A

Minimum Bill is the Demand Charge

* Monthly Billing Demand

The greatest of the following (expressed in kV.A):

a) measured demand; or
b) 80% of the highest measured demand in any of the previous months of December, January and February; or
c) 25% of contract demand; or
d) 25% of the highest measured demand in any of the previous 12 months.

GENERAL SERVICE - MEDIUM
Billing Demand Exceeding 200 kV.A
(Utility owned transformation)

Zone 1
Basic Charge ..... $ 13.24

PLUS

Energy Charge: ALL kW.h ..... @ 1.691 ¢/kW.h

PLUS

Demand Charge: per kV.A of Monthly Billing Demand* ..... @ $7.00/kV.A

Minimum Bill is the Basic Charge PLUS the Demand Charge.

PLANT OPERATING CONDITIONS AND CALCULATIONS OF MONTHLY BILL

Given:

Measured Demand 300 kV.A
and
Consumption 75 000 kW.h per month

Bill Calculation:

Basic Charge		$ 13.24
PLUS		
Energy Charge: 75 000 kW.h @ $1.691 ¢ =		$1,268.25
PLUS		
Demand Charge: 300 kV.A @ $7.00	=	$2,100.00
		$3,381.49

LOAD FACTOR IMPROVEMENT

Monthly Load Factor is the ratio of:

$$\frac{\text{No. of Hours "In Use" During the Month}}{\text{No. of Hours "Available" in the Month}} \times 100\%$$

$$\frac{\text{Kilowatt Hours Used}}{\text{kV.A of Billing Demand X 730 hours}} \times 100\%$$

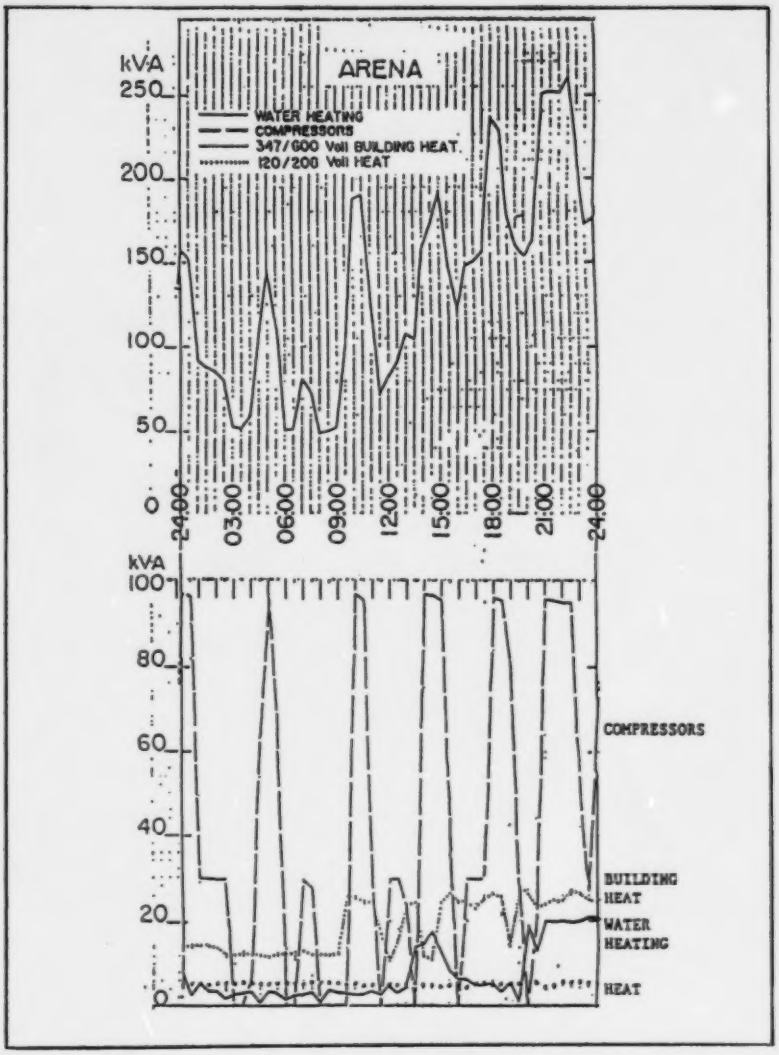
Consider the following example:

Billing Demand [Uncontrolled]	300 kV.A
Billing Demand [Reduced by Load Shifting]	275 kV.A

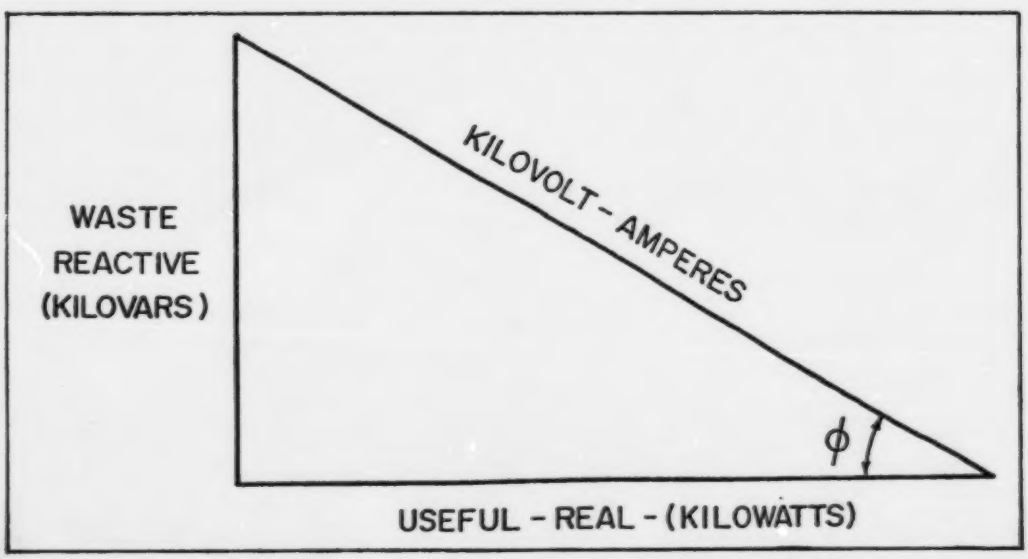
Potential Saving on Demand Charge

[300 kV.A - 275 kV.A]
25 kV.A X $7.00 = $175.00 per month

% Savings: $175.00/$3,381.49 = 5.2%



POWER FACTOR



SAMPLE MONTHLY BILL
(Without Capacitor)
at 0.80 Power Factor
Corrected to 0.95 Power Factor

Without Capacitor		
Basic Charge:	$ 13.24	
PLUS		
Energy Charge:	$ 1,268.25	
PLUS		
Demand Charge:		
275 kV.A @ $7.00	$ 1,925.00	$ 3,206.48
With Capacitor		
Basic Charge:	$ 13.24	
PLUS		
Energy Charge:	$ 1,268.25	
PLUS		
Demand Charge:		
275 x 0.80 / 0.95 = 232 kV.A		
232 kV.A @ $7.00	$ 1,624.00	$ 2,905.48

Potential Saving: $301.00 (9.4%) per month

DEMAND RACHET

Consider the following example:

June Billing Demand is the greatest of:

(a) Measured Demand	205 kV.A or
(b) 80% of February Demand 300 kV.A .80 x 300	240 kV.A or
(c) Contract Demand 500 kV.A .25 x 500	125 kV.A or
(d) 25% of highest in last 12 months 300 kV.A x .25	75 kV.A
June Billing Demand is	240 kV.A
Additional cost for June Due to Winter Rachet (240 - 205 kV.A) 35 kV.A x $7.00	$245.00

SUMMARY OF MONTHLY SAVINGS

Power Factor Improvement	$ 301.00
Load Factor Improvement	$ 175.00
Total Monthly Savings	$ 476.00
Given:	
Monthly Cost of $2,000 Savings	23.8%
Monthly Cost of $3,000 Savings	15.9%

CONFINED ENTRY

Garry Hildebrand
Manitoba Environment and Workplace Safety and Health
Workplace Safety and Health Division
Bldg. 2, 139 Tuxedo Avenue
Winnipeg MB
R3N 0H6

ABSTRACT

A 'confined space' refers to a work area which is not intended for continuous work occupancy, and has by design, structure, location, limited or restricted entry and exit. The space may contain or produce dangerous accumulations of hazardous gases, vapours, mists, dusts, fumes, fog, lack of enrichment of oxygen, biological agents, faster than natural ventilation can remove the hazards.

The basic concept behind confined entry is to identify and evaluate all the potential risks associated with the entry, and develop a procedure for and the equipment to be used before a worker enters the space.

EVALUATION OF HYDROGEN SULFIDE GENERATION POTENTIALS WITHIN THE WINNIPEG SOUTH END INTERCEPTOR SYSTEM

Nick Szoke
MacLaren Engineers Inc.
640 - 5 Donald Street
Winnipeg MB
R3L 2T4

ABSTRACT

A report was prepared for the City of Winnipeg Waterworks Waste and Disposal Department assessing the potential for sulfide generation in pipes flowing partially full. The extent of odour and corrosion problems were determined for current and future conditions based on existing wastewater characteristics (strength, flow, temperature), and pipe dimensions (diameter and slope). EPA guidelines were used to identify locations within the interceptor system with severe sulfide generation potential.

A monitoring program was coordinated with the City of Winnipeg to collect data at locations identified as having a severe generation potential. The collected data confirmed that the potential for severe hydrogen sulfide generation was present at monitored locations. The results indicated that locations susceptible to sulfide odours or sulfide included corrosion can be easily identified from wastewater characteristics and pipe dimensions using EPA guidelines. This method of evaluation can easily be applied to any sewerage system.

A SYSTEMS APPROACH TO THE SELECTION OF A SLUDGE DISPOSAL PROGRAM FOR THE CITY OF WINNIPEG

G. Rempel
Wardrop Engineers Inc.
77 Main Street
Winnipeg MB
R3C 3H1

ABSTRACT

The City of Winnipeg is currently completing a major expansion to the North End Water Pollution Control Centre. This plant receives all the sludge from the three wastewater treatment plants in the City of Winnipeg. Until now the City has used a disposal system involving sludge drying beds to dewater the sludge in winter on agricultural land. While the existing operation is efficient and economical it has encountered significant public and regulatory opposition due to odour nuisance. Regulatory orders required the City to develop an alternative to the current sludge disposal program. This paper discusses a systems approach to the methodology of the selection of a sludge disposal program.

A sludge disposal program can consist of many system components. The best combination of the components is unique for every City. The system components must be considered as an integrated train including the sludge disposal process components but also components such as sludge storage, sludge transportation and treatment of side streams. Nontechnical factors, such as public acceptance and regulatory considerations, also have major influences on the selection, planning and design and operation of a system and must be recognized at the outset of a review of potential systems. Because there are so many potential systems for dewatering and disposal of sludge, a systematic approach to the review is necessary in order to ensure that all systems have been considered and all important relevant criteria have been examined.

The approach used for the Winnipeg Study involved an iterative procedures in which less effect options were screened from the list of potential systems until the most appropriate combination of system components was identified. The paper will discuss the logic of the selection process, relevant selection criteria, and the sequence of activities used in deriving the selection system.